JC14 Rec'd PCT/PTO 02 JAN 2002

Express Mail No: EL913300238US

FORM PTO-1390 (REV 11-98) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**	ATTORNEYS DOCKET NUMBER: AEI VRM USNP1 US APPLICATION NO (If known, see 37 CFR 1.5) 10/030379

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/US00/18086	(30.06.00) 30 June 2000	(02.07.99) 02 July 1999

TITLE OF INVENTION
MULTIPLE ELEMENT RECTIFICATION CIRCUIT

APPLICANT(S) FOR DO/EO/US
Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ■ This is the **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is the **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ■ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b)) and PCT articles 22 and 39(1).
4. ■ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ■ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. ■ is transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ has been transmitted by the International Bureau.
   - c. ■ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ■ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ have been transmitted by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ■ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ■ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ■ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ■ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ■ A FIRST preliminary amendment
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and or address letter
16. ■ Other items or information: Application Data Sheet, Power of Attorney, Assignment of Patent Rights, Assignment Recordation Cover Sheet, Express Mail Certificates, firm Letter of Transmittal, and a return receipt postcard.

JC10 Rec'd PCT/PTO 02 JAN 2002

APPLICATION NO (If known, see 37 CFR 1 5	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
	PCT/US00/18086	AEI VRM USNP 1

17. ■ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492(a) (1) - (5):

CALCULATIONS (PTO USE ONLY)

Neither international preliminary examination fee (37 CFR 1 482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO. $1000.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO. $860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. . .$710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4). $690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfy provisions of PCT Article 33(1)-(4) $100.00

ENTER APPROPRIATE BASIC FEE AMOUNT = $100.00 | $

Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	24-20 =	4	X $18.00	$72 00	
Independant claims	2- 3 =	0	X $80.00	$0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+$270.00	$270.00	
TOTAL OF ABOVE CALCULATIONS =				$342.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				$ -0-	
SUBTOTAL =				$342.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$342.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$382.00	
Amount to be.				Refunded	$
Amount to be:				Charged	$382.00

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ■ Please charge my Deposit Account No. 50-1539 in the amount of $ 382.00 to cover the above fees.

c. ■ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any over payment to Deposit Account No 50-1539. A Duplicate copy of this sheet is enclosed

Note: Where the appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending process.

SEND ALL CORRESPONDENCE TO:

[signature]
SIGNATURE

Alfred K. Wiedmann, Jr
NAME (Registration No 48,033)

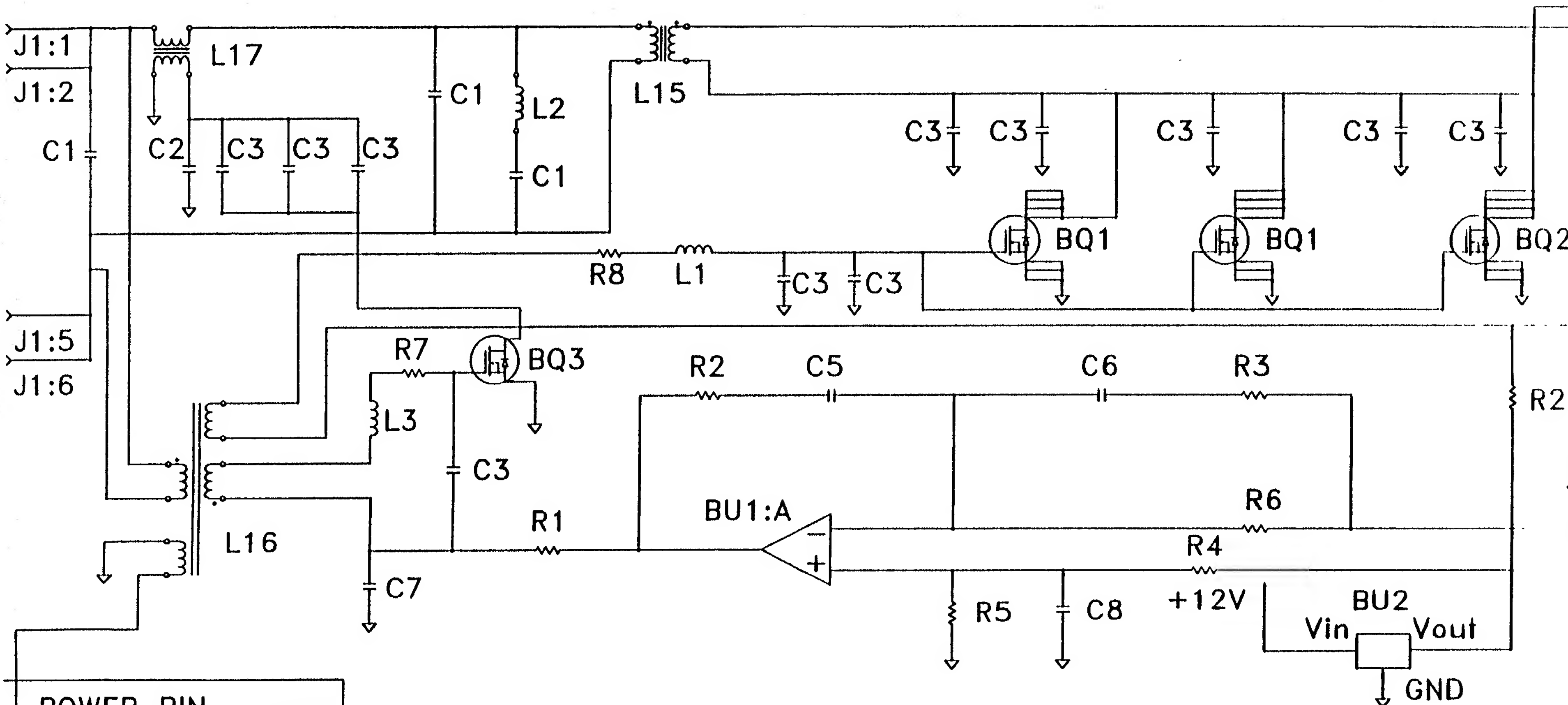
Santangelo Law Offices, P.C
125 South Howes, Third Floor , Fort Collins, CO 80521

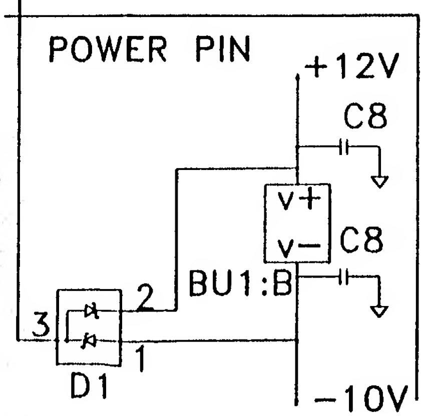
10/030379

JC15 Rec'd PCT/PTO 02 JAN 2002

FORMAL REPLACEMENT DRAWINGS
PCT/US00/18086

10030379 .010202





NOTES: UNLESS OTHERWISE SPECIFIED

1) ALL RESISTANCE VALUES ARE IN OHMS, 1/8W, SM, 1%.
2) ALL CAPACITANCE VALUES ARE IN MICROFARADS, 50V.
3) USED WITH 230X131 PCB.
4) ALL REF DES WITH 'B' AS A PREFIX ARE INSTALLED ON SOLDER SIDE.

Figure 3-11 Left

Capacitors

C1	470PF	100V
C2	1000PF	100V
C3	2200PF	
C4	22uF	10V
C5	100PF	100V
C6	4700PF	100V
C7	5600PF	100V
C8	0.1	

Resistors

R1	124	
R2	10K	
R3	49.9	
R4	3.24K	
R5	1.82K	
R6	499	
R7	5.6	1/2W 5% SM
R8	0.1	1/2W SM

Inductors

L1	330NH
L2	No Value
L3	150NH
L5	100NH

Miscellaneous

BU1:A	AD825
BU1:B	AD825
BU2	AD1585
D1	HSMS2802

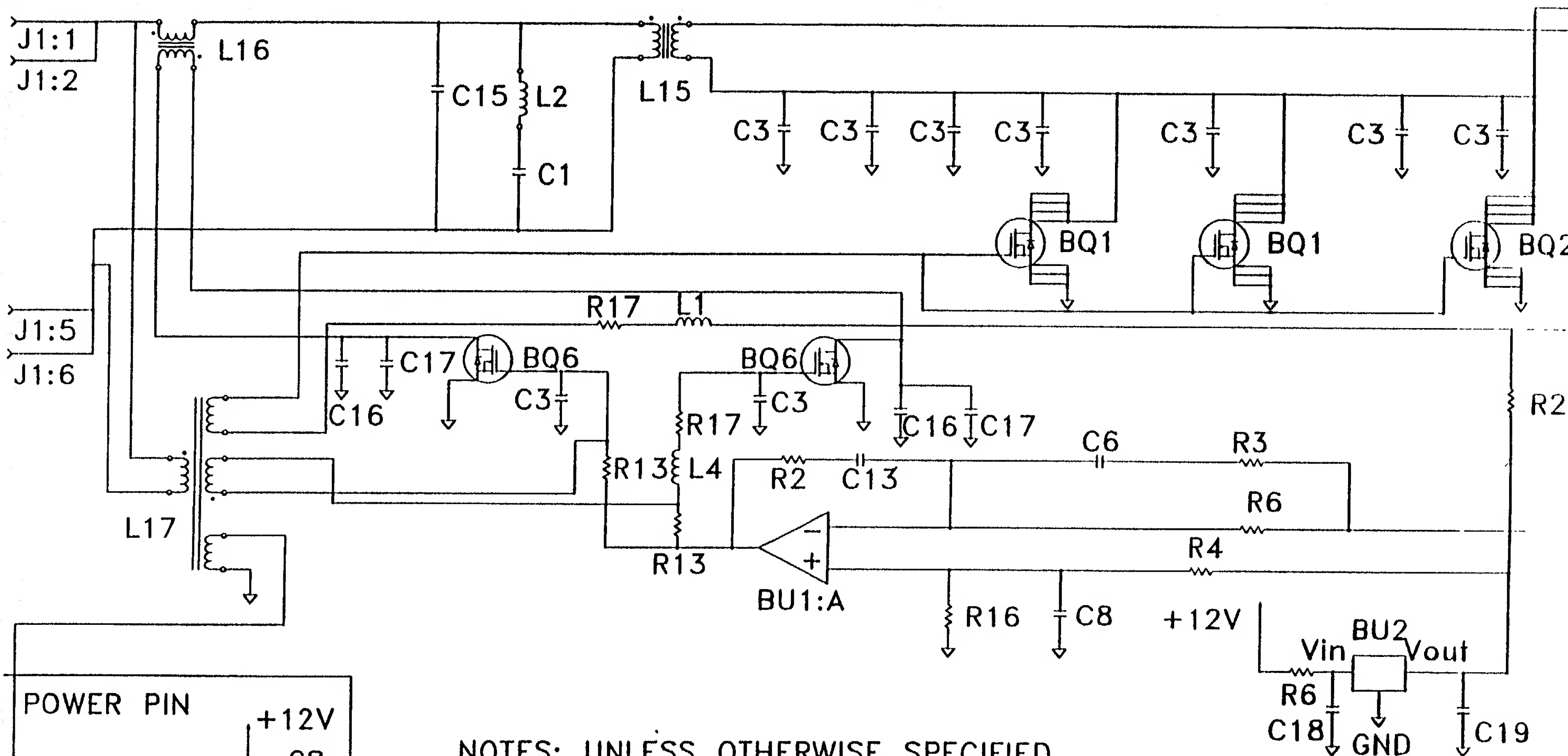
Transformers

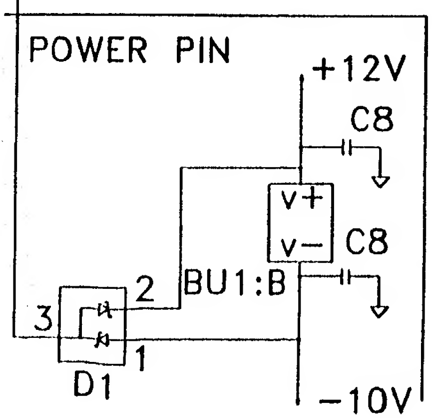
L15	TRANS	L2
L16	TRANS	L4
L17	TRANS	L6

Transistors

BQ1	OPEN
BQ2	M14420T
BQ3	Q1 NOTEST

Figure 3–11 Values





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2) ALL CAPACITANCE VALUES ARE IN MICROFARADS, 50V.
3) USED WITH 230X131 PCB.
4) ALL REF DES WITH 'B' AS A PREFIX ARE INSTALLED ON SOLDER SIDE.

Figure 3–12 Left

Capacitors

C1	470PF	100V
C3	2200PF	
C4	22uF	10V
C6	4700PF	100V
C8	0.1PF	
C15	1500PF	50V
C16	2700PF	100V
C17	680PF	100V
C18	4.7uF	
C19	1uF	

Resistors

R2	10K
R3	49.9
R4	3.24K
R6	499
R13	100
R15	24.9K
R16	1.82K
R17	OPEN 1/2W

Inductors

L1	330NH
L2	No Value
L4	OPEN
L5	100NH

Miscellaneous

BU1:A	AD825
BU1:B	AD825
BU2	AD1585

D1 HSMS2802

Transformers

L15	TRANS	L2
L16	TRANS	L4
L17	TRANS	L6

Transistors

BQ1	OPEN
BQ2	M14420T
BQ6	RFD16NO06LESM

Figure 3-12 Values

10/030379

JC15 Rec'd PCT/PTO 02 JAN 2002

Express Mail No: EL913300238US
Attorney Docket: AEI VRM USNP1

IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE

In Re the Application of: Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov

Serial Number: (original US) 60/142,102 New: ____________
(PCT) PCT/US00/18086

Filed: (original US) 02 July 1999 New: ____________
(PCT) 30 June 2000

For: (Old Title): System for Controlling the Delivery of Power to DC Computer Components

(New Title): Multiple Element Rectification Circuit

CERTIFICATE OF EXPRESS MAILING

I, Barbara Graves, hereby certify to the truth of the following items:

1. I am an employee of Santangelo Law Offices, P.C., 125 South Howes, Third Floor, Fort Collins, Colorado 80521.

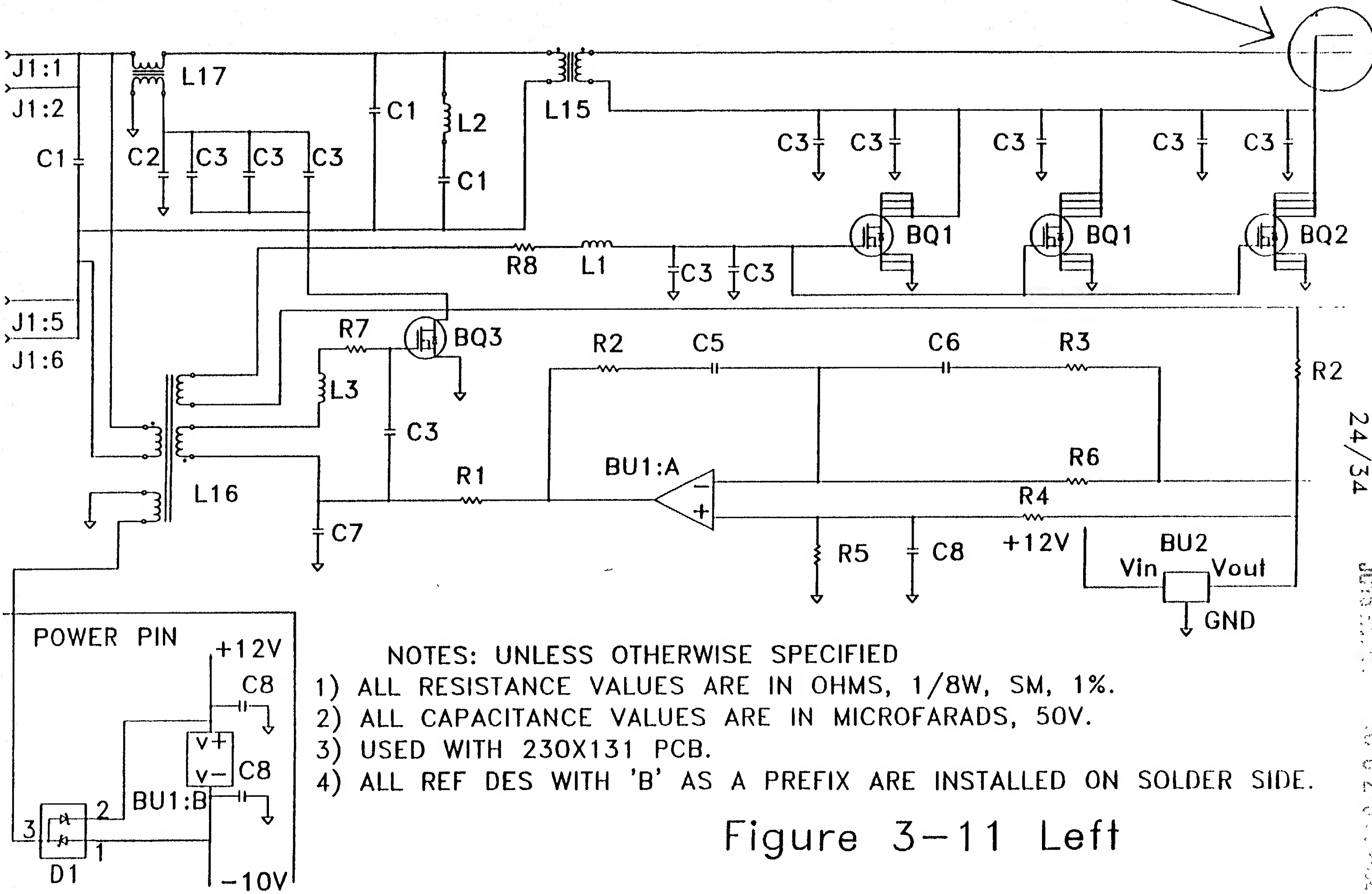
2. I have this day deposited the attached copy of the International PCT application as filed consisting of 106 pages of specification and 34 pages of drawings, along with copies of 3 separate Article 34 amendments, with the United States Postal Service as "Express Mail" for mailing to the Assistant Commissioner of Patents, Box PCT,
Washington, D.C. 20231.

Dated this 2nd day of January, 2002.

Barbara Graves

CHANGES TO FORMAL DRAWINGS

NOTE CHANGE



NOTES: UNLESS OTHERWISE SPECIFIED
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Figure 3–11 Left

NOTE CHANGE

Capacitors

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C6	4700PF	100V
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R8	0.1	1/2W SM

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L1	330NH
L2	No Value
L3	150NH
L5	100NH

Miscellaneous

BU1:A	AD825
BU1:B	AD825
BU2	AD1585

Transformers

L15	TRANS	L2
L16	TRANS	L4
L17	TRANS	L6

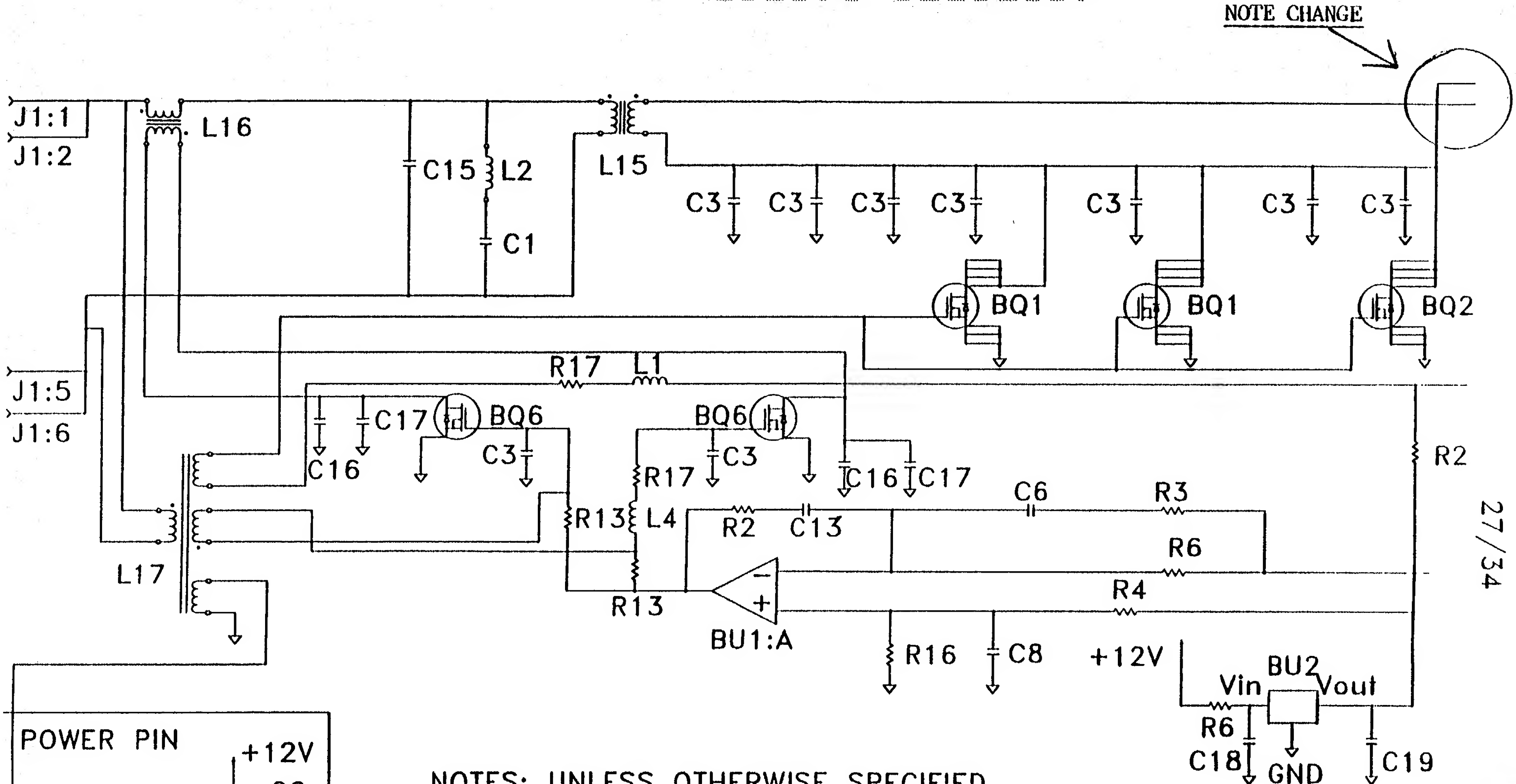
D1	HSMS2802

Transistors

BQ1	OPEN
BQ2	M14420T
BQ3	Q1 NOTEST

Figure 3-11 Values

10/030379



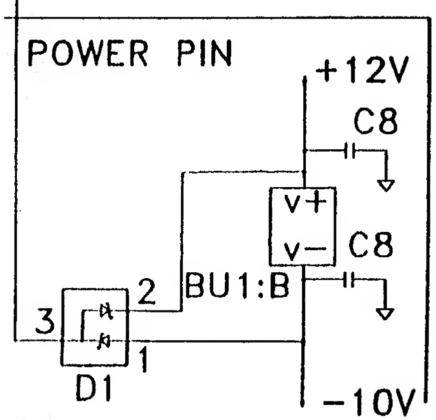


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Figure 3–12 Left

NOTE CHANGE

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C16	2700PF	100V
C17	680PF	100V
C18	4.7uF	
C19	1uF	

Resistors

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R13	100
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BU1:A	AD825
BU1:B	AD825
BU2	AD1585

D1	HSMS2802

Transformers

L15	TRANS	L2
L16	TRANS	L4
L17	TRANS	L6

Transistors

BQ1	OPEN
BQ2	M14420T
BQ6	RFD16NO06LESM

Figure 3-12 Values

10/030379

JC10 Rec'd PCT/PTO 02 JAN 2002

Express Mail No: EL913300238US
Attorney Docket: AEI VRM USNP1

IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE

In Re the Application of:	Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov	
Serial Number:	(original US) 60/142,102 (PCT) PCT/US00/18086	New: ____________
Filed:	(original US) 02 July 1999 (PCT) 30 June 2000	New: ____________
For:	(Old Title): System for Controlling the Delivery of Power to DC Computer Components (New Title): Multiple Element Rectification Circuit	

PRELIMINARY AMENDMENT

This national stage application presents only claims for examination which have been indicated in the International Preliminary Examination Report prepared by the United States Patent and Trademark Office as satisfying the criteria of PCT Article 33(1)-(4) as to novelty, inventive step and industrial applicability. The applicants have amended the claims section of the application only to the extent necessary to cancel certain claims. As such, the applicants have paid the fee as set forth in 37 C.F.R. §1.492(a)(4). The applicants respectfully request that this application be taken out of order pursuant to 37 C.F. R. §1.496(b).

In accordance with the amendment directions provided in 37 CFR 1.121, please add the priority claim, amend the title, amend the abstract, and cancel without prejudice claims 1-253, 267-327 and 338-357, each as indicated in the attached Exhibits A and B. Pursuant to the Rule, the exhibits are to be considered as part of this response. Note that the amendments to the claims are to be made with respect to the application as it existed

after the second of two International Preliminary Examination Reports (IPER) was issued (the mailing date of the second IPER is 9 November 2001) in which 357 claims existed in the application and which considered amendments made by three Article 34 Amendments. Exhibit A provides a restated set of all remaining claims, some of which have been amended, and Exhibit B provides the required marked up version of those specific claims that are hereby amended. The claims remaining in this case for examination - claims 254-266 and 328-337 - each satisfying the criteria of PCT Articles 33(1)-(4) as to novelty, inventive step and industrial applicability, are set out in Exhibit A as a clean version of the claims as amended for the convenience of the examiner.

The amendments as submitted in Exhibit A should be understood to be made as a practicality only, and should not to be construed as creating any situation of file wrapper estoppel or the like as all rights are expressly reserved and may be pursued in this or other applications, such as divisionals, continuations, or continuations-in-part if desired.

REMARKS

The above-identified patent application is one of two United States national stage applications of international PCT Patent Application No. PCT/US00/18086. The United States was designated as the International Search Authority and as the International Preliminary Examining Authority. The original PCT application was amended to include 357 claims, each satisfying the criteria of PCT Article 33(1)-(4) as to novelty, inventive step and industrial applicability. The applicants have amended the claims section of the application only to the extent necessary to cancel certain claims.

When all the claims in a PCT application satisfy each of the criteria of PCT Article 33(1)-(4) and when the applicant only amends the claims such that the remaining claims satisfy the criteria of PCT Article 33(1)-(4), the applicant may pay the fee set forth in 37 C.F.R. §1.492(a)(4) and request that the application be taken out of order pursuant to 37 C.F. R. §1.496(b). As such, the applicants have paid the fee as set forth in 37

C.F.R. §1.492(a)(4) and respectfully request that this application be taken out of order for examination.

The application was considered to have met the requirement of unity of invention throughout the international search and the international examination and no invitation to pay additional fees was made under Article 17 (3)(a). During the national stage of a PCT application when considering unity of invention of claims under 35 U.S.C. §§121, 371, and 372; Rule 13.1 and 13.2 should be followed without regard to the practice in national applications filed under 35 U.S.C. §111 and MPEP §1850. Unity of invention is present when there is a "technical relationship" among the claimed inventions involving one or more of the same or corresponding "special technical features". Rule 13.2 PCT. The expression "special technical features" means those technical features that define a contribution which each of the claimed inventions, considered as a whole, makes over the prior art. Rule 13.2 PCT. Moreover, the rules specifically allow for inventions within the same application when there is a relationship between a product, process, and use. MPEP §1850 C (A). Illustrations of Particular Situations.

In the original application, an unusually large number of claims were presented in order to adequately claim the various aspects of the present invention(s) in dependent and alternatively independent fashions. The applicants have voluntarily reduced the number of claims by canceling claims 1-253, 267-327 and 338-357 as filed in the original application, leaving only claims 254-266 and 328-337 for examination, including 2 closely related independent claims having unity of invention along with their dependent claims.

Thus, the applicants have voluntarily reduced the number of claims to assist the examiners in their efforts and to expedite the examination. The voluntary reduction in claim number is not to be construed as a waiver of any right to file other applications such as continuations, divisions, continuations-in-part, or similar applications and have the remaining claims examined without any reduction in breadth. The applicants

respectfully requests that each of claims 254-266 and 328-337 be examined as single group as part of this United States national stage application.

The applicants have set out a clean version of the claims above (Exhibit A) and a version with markings to show changes made (Exhibit B) pursuant to 37 C.F.R. §1.121. The applicants respectfully requests allowance of the claims at the examiner's earliest convenience.

CONCLUSION

Claims 1-253, 267-327 and 338-357 have been cancelled without prejudice. Claims 254-266 and 328-337 remain in the application. Each of claims 254-266 and 328-337 were indicated in the most recent International Preliminary Examination Report as satisfying the criteria of PCT Article 33(1)-(4), and have unity of invention. The claims have been amended by the applicants only to the extent necessary to voluntarily reduce the number of claims. The applicants also request that a priority claim be added to the specification and that the Abstract and Title be amended as indicated. The applicants, having satisfied the requirements of 37 C.F. R. §1.496(b) and unity of invention, respectfully request that the application be taken out of order and that claims 254-266 and 328-337 be examined as a single group.

Dated this 2nd day of January, 2002.

Respectfully Submitted,
SANTANGELO Law Offices, P.C.

Alfred K. Wiedmann Jr.
PTO Reg. No. 48,033
125 South Howes, Third Floor
Fort Collins, CO 80521
(970) 224-3100

prelamend1

EXHIBIT A

(IN THE SPECIFICATION)

Please insert the following new title in place of the existing title at top of page 1:

MULTIPLE ELEMENT RECTIFICATION CIRCUIT

Please add the following paragraph after the title on page 1:

This application is the United States National Stage of International Application No. PCT/US00/18086, filed June 30, 2000, which claims the benefit of and priority from: (a) United States Provisional Application Number 60/142,102 filed July 2, 1999; (b) United States Provisional Application Number 60/144,342, filed July 16, 1999; (c) PCT Application Number PCT/US00/07779, the specification of which was filed on March 23, 2000 and designating the United States of America, this PCT Application being filed while the Original US Application was pending; (d) United States Application Number 09/534,641 filed March 23, 2000; and (e) United States Application Number 09/584,412 filed May 31, 2000; each hereby incorporated by reference.

Please amend the abstract paragraph on page 123 to read as follows:

VII. ABSTRACT

Apparatus are disclosed for controlling the delivery of power to DC components such as computer components, microprocessors or the like. Designs of rectifier circuitry are presented which are appropriate for faster components, lower voltages, and higher

currents. Embodiments are especially suited to applications which cause rapid changes in the conductance of the load, even in the sub-microsecond time domain as is common in computer applications and the like and in powering electronics equipment, especially a distributed system and especially a system wherein low voltage at high current is required. Embodiments and sub elements provide energy storage for low voltage, high current electronic loads, an ability to supply current with rapid time variation, providing extremely low inductance connections, permitting components to be located relatively remotely from the powered electronic load.

EXHIBIT A

(IN THE CLAIMS)

VI. CLAIMS

What is claimed is:

254. A rectification circuit comprising:
    a. a first rectifier element;
    b. a second rectifier element;
    c. an overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive; and
    d. a DC output responsive to said first rectifier element and said second rectifier element.

255. A rectification circuit as described in claim 254 wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive causes conduction in both said first rectifier element and said second rectifier element to simultaneously occur at least some time.

256. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element.

257. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first controllable diode element and wherein said second rectifier element comprises a second controllable diode element.

258. A rectification circuit as described in claim 254 wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control

system configured to create a conduction angle in each of said first and said second rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which is less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on each said rectifier at the time when said rectifier is switched to a conductive state.

259. A rectification circuit as described in claim 254 or 258 wherein said rectification circuit further comprises high voltage response circuitry which subjects said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state.

260. A rectification circuit as described in claim 259 wherein said high voltage response circuitry subjects said first and said second rectifier elements to a voltage selected from a group consisting of at least about 1.4 times a DC output voltage, at least about 8 times a DC output voltage, at least about 15 volts, and at least about 20 volts.

261. A rectification circuit as described in claim 254 and further comprising a transformer element to which said first and said second rectifier elements are responsive.

262. A rectification circuit as described in claim 261 and further comprising a total capacitance and a transformer leakage inductance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control

system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and said total capacitance are coordinated with said transformer leakage inductance.

263. A rectification circuit as described in claim 262 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

264. A rectification circuit as described in claim 261 and further comprising a transformer leakage inductance, wherein said rectification circuit affirmatively utilizes said transformer leakage inductance as an energy storage element.

265. A rectification circuit as described in claim 264 and further comprising a total capacitance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and said total capacitance are coordinated with said transformer leakage inductance.

266. A rectification circuit as described in claim 265 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

328. A rectification circuit comprising:

a. a first rectifier element;

b. a second rectifier element;

c. a passive sinusoidal drive system to which said first rectifier element and said second rectifier element are responsive; and

d. a DC output responsive to said first rectifier element and said second rectifier element.

329. A rectification circuit as described in claim 328 and further comprising a synchronous rectifier control system to which said first and second rectifier elements are responsive.

330. A rectification circuit as described in claim 328 wherein said passive sinusoidal drive system comprises a gate drive transformer element.

331. A rectification circuit as described in claim 328 wherein said sinusoidal drive system to which said first and second rectifier elements are responsive comprises a high frequency sinusoidal drive system.

332. A rectification circuit as described in claim 331 wherein said high frequency sinusoidal drive system comprises a drive system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second synchronous rectifier elements, and any permutations or combinations of the above.

333. A rectification circuit as described in claim 329 wherein said synchronous rectifier control system comprises a bias input.

334. A rectification circuit as described in claim 333 wherein said bias input comprises a DC input.

335. A rectification circuit as described in claim 333 wherein said bias input comprises a low frequency input.

336. A rectification circuit as described in claim 334 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said DC input.

337. A rectification circuit as described in claim 335 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said low frequency input.

EXHIBIT B

VERSION WITH MARKINGS TO SHOW CHANGES MADE

(IN THE SPECIFICATION)

Please amend the title on page 1, lines 1 and 2 as follows:

[SYSTEM FOR CONTROLLING THE DELIVERY OF POWER TO DC COMPUTER COMPONENTS]
MULTIPLE ELEMENT RECTIFICATION CIRCUIT

Please add the following paragraph after the title on page 1:

This application is the United States National Stage of International Application No. PCT/US00/18086, filed June 30, 2000, which claims the benefit of and priority from: (a) United States Provisional Application Number 60/142,102 filed July 2, 1999; (b) United States Provisional Application Number 60/144,342, filed July 16, 1999; (c) PCT Application Number PCT/US00/07779, the specification of which was filed on March 23, 2000 and designating the United States of America, this PCT Application being filed while the Original US Application was pending; (d) United States Application Number 09/534,641 filed March 23, 2000; and (e) United States Application Number 09/584,412 filed May 31, 2000; each hereby incorporated by reference.

Please amend the abstract on page 123 as follows:

VII. ABSTRACT

[Method and apparatus are disclosed for controlling the delivery of power to DC components such as computer components, microprocessors or the like. Designs of

voltage regulation modules (112) are presented which are appropriate for faster components, lower voltages, and higher currents. Embodiments are especially suited to applications which cause rapid changes in the conductance of the load, even in the sub-microsecond time domain as is common in computer applications and the like and in powering electronics equipment, especially a distributed system and especially a system wherein low voltage at high current is required. Embodiments and sub elements provide energy storage for low voltage, high current electronic loads, an ability to supply current with rapid time variation, providing extremely low inductance connections, permitting VRM's (112) and the like to be located relatively remotely from the powered electronic load (186), and a steady voltage from a transformer isolated, high frequency AC to DC converter (102) under varying load without the necessity for feedback control, among other aspects.] Apparatus are disclosed for controlling the delivery of power to DC components such as computer components, microprocessors or the like. Designs of rectifier circuitry are presented which are appropriate for faster components, lower voltages, and higher currents. Embodiments are especially suited to applications which cause rapid changes in the conductance of the load, even in the sub-microsecond time domain as is common in computer applications and the like and in powering electronics equipment, especially a distributed system and especially a system wherein low voltage at high current is required. Embodiments and sub elements provide energy storage for low voltage, high current electronic loads, an ability to supply current with rapid time variation, providing extremely low inductance connections, permitting components to be located relatively remotely from the powered electronic load.

EXHIBIT B

VERSION WITH MARKINGS TO SHOW CHANGES MADE

(IN THE CLAIMS)

Please cancel without prejudice claims 1-253, 267-327 and 338-357.

VI. CLAIMS

What is claimed is:

254. A rectification circuit comprising:
    a. a first rectifier element;
    b. a second rectifier element;
    c. an overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive; and
    d. a DC output responsive to said first rectifier element and said second rectifier element.

255. A rectification circuit as described in claim 254 wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive causes conduction in both said first rectifier element and said second rectifier element to simultaneously occur at least some time.

256. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element.

257. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first controllable diode element and wherein said second rectifier element comprises a second controllable diode element.

258. A rectification circuit as described in claim 254 wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which is less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on each said rectifier at the time when said rectifier is switched to a conductive state.

259. A rectification circuit as described in claim 254 or 258 wherein said rectification circuit further comprises high voltage response circuitry which subjects said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state.

260. A rectification circuit as described in claim 259 wherein said high voltage response circuitry subjects said first and said second rectifier elements to a voltage selected from a group consisting of at least about 1.4 times a DC output voltage, at least about 8 times a DC output voltage, at least about 15 volts, and at least about 20 volts.

261. A rectification circuit as described in claim 254 and further comprising a transformer element to which said first and said second rectifier elements are responsive.

262. A rectification circuit as described in claim 261 and further comprising a total capacitance and a transformer leakage inductance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and said total capacitance are coordinated with said transformer leakage inductance.

263. A rectification circuit as described in claim 262 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

264. A rectification circuit as described in claim 261 and further comprising a transformer leakage inductance, wherein said rectification circuit affirmatively utilizes said transformer leakage inductance as an energy storage element.

265. A rectification circuit as described in claim 264 and further comprising a total capacitance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and said total capacitance are coordinated with said transformer leakage inductance.

266. A rectification circuit as described in claim 265 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

328. A rectification circuit comprising:

a. a first rectifier element;

b. a second rectifier element;

c. a passive sinusoidal drive system to which said first rectifier element and said second rectifier element are responsive; and

d. a DC output responsive to said first rectifier element and said second rectifier element.

329. A rectification circuit as described in claim 328 and further comprising a synchronous rectifier control system to which said first and second rectifier elements are responsive.

330. A rectification circuit as described in claim 328 wherein said passive sinusoidal drive system comprises a gate drive transformer element.

331. A rectification circuit as described in claim 328 wherein said sinusoidal drive system to which said first and second rectifier elements are responsive comprises a high frequency sinusoidal drive system.

332. A rectification circuit as described in claim 331 wherein said high frequency sinusoidal drive system comprises a drive system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at

least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second synchronous rectifier elements, and any permutations or combinations of the above.

333. A rectification circuit as described in claim 329 wherein said synchronous rectifier control system comprises a bias input.

334. A rectification circuit as described in claim 333 wherein said bias input comprises a DC input.

335. A rectification circuit as described in claim 333 wherein said bias input comprises a low frequency input.

336. A rectification circuit as described in claim 334 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said DC input.

337. A rectification circuit as described in claim 335 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said low frequency input.

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Attorney Docket: AEI VRM USNP1

IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE

In Re the Application of: Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov

Serial Number: (original US) 60/142,102 New: ____________
(PCT) PCT/US00/18086

Filed: (original US) 02 July 1999 New: ____________
(PCT) 30 June 2000

For: (Old Title): System for Controlling the Delivery of Power to DC Computer Components

(New Title): Multiple Element Rectification Circuit

CERTIFICATE OF EXPRESS MAILING

I, Barbara Graves, hereby certify to the truth of the following items:

1. I am an employee of Santangelo Law Offices, P.C., 125 South Howes, Third Floor, Fort Collins, Colorado 80521.

2. I have this day deposited the attached First Preliminary Amendment with the United States Postal Service as "Express Mail" for mailing to the Assistant Commissioner of Patents, Box PCT, Washington, D.C. 20231.

Dated this 2nd day of January, 2002.

Barbara Graves

10/030379
JC10 Rec'd PCT/PTO 02 JAN 2002
PCSupVRM
Express Mail No: EL728559156US

IN THE UNITED STATES PATENT AND
TRADEMARK OFFICE:
PCT BRANCH

In Re the Pending International Application of: Advanced Energy Industries, Inc.

International Application Number: PCT/US00/18086

International Filing Date: 30 June 2000 (30.06.00)

Priority Date: 02 July 1999 (02.07.99)

For: System for Controlling the Delivery of Power to DC Computer Components

Receiving Office: RO/US

AMENDMENT UNDER ARTICLE 34 WITH A DEMAND FOR AN INTERNATIONAL PRELIMINARY EXAMINATION

Pursuant to Article 34, the Applicant hereby amends the claims in the referenced application and the requests that the examiner consider the amendment prior to the International Preliminary Examination. Accordingly, the attached replacement sheets 46, 59, 60, and 72 and this amendment are submitted.

A. AMENDMENT

Please replace pages 46, 59, 60, and 72, as originally filed or previously amended with the attached replacement pages 46, 59, 60, and 72.

B. INDICATION OF DIFFERENCES

As required by Rule 53.9(c), Rule 66.8, and as set forth in paragraph 322 of the PCT Applicant's Guide, the following differences exist with respect to the claims as originally filed:

Claims 1, 51, 54, and 105 have been amended to correct a typographic error replacing the word "alternative" with the word "alternating."

The foregoing amendments do not go beyond the disclosure in the international application as filed and should be considered in establishing the first international examination report.

C. CONCLUSION

The above changes should be considered and included in the examination of the application. A favorable examination report as to all pending claims is requested.

Dated this 2nd day of February, 2001.

Respectfully Submitted,
SANTANGELO LAW OFFICES, P.C.

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VI. CLAIMS

What is claimed is:

1. A DCpowered computer system comprising:

   a. a utility power input which supplies AC utility power having a line frequency;

   b. a line voltage rectifier element which converts said AC utility power to a DCsignal;

   c. an inverter element responsive to said DCsignal which establishes an alternating power output;

   d. a frequency driver which controls said inverter element to establish a distribution frequency;

   e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at least one distribution voltage;

   f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

   g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising;

   1) an alternating power input;

   2) at least one voltage regulation module transformer which is responsive to said alternating power input;

   3) a first switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

   4) a second switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

   5) a passive rectifier control to which said first and said second switched voltage regulation module rectifier elements are responsive;

   6) a bias input to which said passive rectifier control is responsive;

   7) a second harmonics trap which is responsive to said first and said second voltage regulation module rectifier elements; and

to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising:

1) an alternating power input;

2) at least one voltage regulation module transformer element which is responsive to said alternating power input;

3) at least one voltage regulation module rectifier element which is responsive to said voltage regulation module transformer element; and

4) a substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element; and

h. at least one computer component responsive to said substantially non-capacitive DC output system.

52. A DC powered computer system as described in claim 51 wherein said at least one computer component responsive to said substantially non-capacitive DC output system comprises a low voltage, high current computer component.

53. A DC powered computer system as described in claim 51 wherein said substantially non-capacitive DC output system comprises a DC output system having an effective

capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

54. A voltage regulation module comprising:

a. an alternating power input;

b. at least one voltage regulation module transformer which is responsive to said alternating power input;

c. a first switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

d. a second switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

e. a passive rectifier control to which said first and said second switched voltage regulation module rectifier elements are responsive;

f. a bias input to which said passive rectifier control is responsive;

g. a second harmonics trap which is responsive to said first and said second voltage regulation module rectifier elements; and

h. a substantially non-capacitive DC output system which is responsive to said second harmonics trap.

55. A DC powered computer system as described in claim 17 wherein said first voltage regulation module rectifier element comprises a first switched voltage regulation module rectifier element and wherein said second voltage regulation module rectifier element comprises a second switched voltage regulation module rectifier element.

56. A DC powered computer system as described in claim 17 wherein said first voltage regulation module rectifier element comprises a first controllable diode element and wherein said second voltage regulation module rectifier element comprises a second

3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second switched voltage regulation module rectifiers, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of said sinusoidal drive system, and any permutations or combinations of the above.

104. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. establishing a component DC supply voltage;

f. transmitting said component DC supply voltage to an electrically remote computer component; and

g. powering said computer component from said component DC supply voltage.

105. A voltage regulation module comprising:

a. an alternating power input;

b. at least one voltage regulation module transformer which is responsive to said alternating power input;

c. at least one voltage regulation module rectifier element which is responsive to said voltage regulation module transformer element; and

d. a substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element.

106. A DC powered computer system as described in claim 105 wherein said substantially non-capacitive DC output system comprises a DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less

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Express Mail No: EL728558323US

IN THE UNITED STATES PATENT AND
TRADEMARK OFFICE:
PCT BRANCH

In Re the Pending International Application of: Advanced Energy Industries, Inc.

International Application Number: PCT/US00/18086

International Filing Date: 30 June 2000 (30.06.00)

Priority Date: 02 July 1999 (02.07.99)

For: System for Controlling the Delivery of Power to DC Computer Components

Receiving Office: RO/US

AMENDMENT UNDER ARTICLE 34
in accordance with PCT Rule 66.1(b) and (d)

Pursuant to Article 34, the Applicant hereby amends the claims in the referenced application and requests that the examiner consider the amendment prior to the International Preliminary Examination. Accordingly, the attached 19 replacement sheets and this amendment are submitted.

AMENDMENT

Please replace pages 105 and 106 as originally filed or previously amended with the attached replacement pages 105 through 123. Replacement pages 105 through 123 have been provided in triplicate for the convenience of the Office.

In the claims:

The Applicant has introduced newly submitted claims 254 through 357 in replacement sheets 105 through 122.

In the specification:

In accordance with the introduced claims described above, the Abstract has been provided as replacement page 123, corresponding to the above-mentioned amendments.

INDICATION OF DIFFERENCES

As required by Rule 66.8, and as set forth in paragraphs 345, 349 and 397 of the PCT Applicant's Guide, no differences exist with respect to the claims as originally filed, as claims 1 through 253 have remained unchanged. The Applicant has introduced newly submitted claims 254 through 357 to claim additional concepts of the present invention disclosed in the application.

REMARKS

The Applicant has requested that the present amendment to the claims be considered by the Examiner prior to the establishment of the Written Opinion. Pursuant to the telephone conversation between Examiner Adolph Bernhane and Applicant's representative 12 June 2001, the present amendment to the claims would be considered in the forthcoming Written Opinion. It is the Applicant's understanding that the International Preliminary Examining Authority has not begun to draw up the Written Opinion, as provided in Rule 66.4 and PCT Applicant's Guide paragraph 394. The Applicant sincerely appreciates the Examiner's willingness to consider the present Article 34 amendment in conjunction with the anticipated Written Opinion.

CONCLUSION

The above changes should be considered and included in the examination of the application, particularly for the forthcoming Written Opinion. A favorable examination report as to all pending claims is requested.

Dated this 15 day of June, 2001.

Respectfully Submitted,
SANTANGELO LAW OFFICES, P.C.

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step of powering said computer component from said component DC supply voltage comprises the step of powering said computer component from said component DC supply voltage at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

251. A method of powering a DC computer system as described in claims 247 or 250 wherein said step of subjecting said voltage regulation module rectifier element to a high voltage when said voltage regulation module rectifier element is in said non-conducting state comprises the step of subjecting said voltage regulation module rectifier element to a voltage selected from a group consisting of at least about 1.4 times the voltage to which said voltage regulation module rectifier element is subjected in a conducting state, at least about 8 times the voltage to which said voltage regulation module rectifier element is subjected in a conducting state, at least about 15 volts, and at least about 20 volts when said voltage regulation module rectifier element is in a non-conducting state.

252. Methods substantially as described hereinbefore and with reference to any of the accompanying examples.

253. Apparatuses substantially as described hereinbefore and with reference to any of the accompanying examples.

254. A rectification circuit comprising:

a. a first rectifier element;

b. a second rectifier element;

c. an overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive; and

d. a DC output responsive to said first rectifier element and said second rectifier element.

255. A rectification circuit as described in claim 254 wherein said overlapping conduction

rectifier control system to which said first and said second rectifier elements are responsive causes conduction in both said first rectifier element and said second rectifier element to simultaneously occur at least some time.

256. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element.

257. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first controllable diode element and wherein said second rectifierelement comprises a second controllable diode element.

258. A rectification circuit as described in claim 254 wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which is less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on each said rectifier at the time when said rectifier is switched to a conductive state.

259. A rectification circuit as described in claim 254 or 258 wherein said rectification circuit further comprises high voltage response circuitry which subjects said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state.

260. A rectification circuit as described in claim 259 wherein said high voltage response circuitry subjects said first and said second rectifier elements to a voltage selected from a group consisting of at least about 1.4 times a DC output voltage, at least about 8 times a DC output voltage, at least about 15 volts, and at least about 20 volts.

261. A rectification circuit as described in claim 254 and further comprising a transformer element to which said first and said second rectifier elements are responsive.

262. A rectification circuit as described in claim 261 and further comprising a total capacitance and a transformer leakage inductance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and said total capacitance are coordinated with said transformer leakage inductance.

263. A rectification circuit as described in claim 262 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier elementcomprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

264. A rectification circuit as described in claim 261 and further comprising a transformer leakage inductance, wherein said rectification circuit affirmatively utilizes said transformer leakage inductance as an energy storage element.

265. A rectification circuit as described in claim 264 and further comprising a total capacitance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and

said total capacitance are coordinated with said transformer leakage inductance.

266. A rectification circuit as described in claim 265 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

267. A method of current rectification, comprising the steps of:

a. providing a first rectifier element and a second rectifier element;

b. providing an AC input to said first and second rectifier elements:

c. controlling overlapping conduction of said first and said second rectifier elements; and

d. producing a DC output.

268. A power supply circuit powering a microprocessor capable of a rapid current demand comprising a DC power supply physically remote from said microprocessor.

269. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said microprocessor comprises a low voltage, high current load and wherein said DC power supply provides a regulated voltage to said load.

270. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said DC power supply provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said DC power supply to said microprocessor, over at least about one inch from said DC power supply to said microprocessor, and over at least about two inches from said DC power supply to said microprocessor.

271. A remote power supply circuit powering a microprocessor capable of a rapid current

demand as described in claim 268 wherein said power supply is electrically remote from said microprocessor.

272. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 further comprising a bypass capacitance adjacent said microprocessor.

273. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 272 wherein said bypass capacitance comprises a total bypass capacitance selected from the group consisting of less than about .2 millifarads and less than about .5 millifarads.

274. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 272 wherein said bypass capacitance comprises a capacitance selected from the group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

275. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said DC power supply comprises a substantially non-capacitive output.

276. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 275 wherein said DC power supply comprises a substantially inductive output.

277. A remote power supply circuit powering a microprocessor capable of a rapidcurrent demand as described in claim 269 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting

of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

278. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 269 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

279. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 269 wherein said microprocessor comprises a microprocessor operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

280. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said DC power supply comprises a voltage regulation module.

281. A method of powering a microprocessor capable of a rapid current demand, comprising the steps of:

a. establishing a DC power supply physically remote from said microprocessor; and

b. remotely powering said microprocessor.

282. A power supply circuit powering a low voltage, high current microprocessor capable of a rapid current demand comprising a DC power supply having a substantially inductive DC output.

283. A power supply circuit powering a microprocessor as described in claim 282 wherein said microprocessor comprises a low voltage, high current load and wherein said DC

power supply provides a regulated voltage to said load.

284. A power supply circuit powering a microprocessor as described in claim 282 wherein said DC power supply is physically remote from said microprocessor.

285. A power supply circuit powering a microprocessor as described in claim 284 wherein said DC power supply provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said DC power supply to said microprocessor, over at least about one inch from said DC power supply to said microprocessor, and over at least about two inches from said DC power supply to said microprocessor.

286. A power supply circuit powering a microprocessor as described in claim 282 wherein said DC power supply is electrically remote from said microprocessor.

287. A power supply circuit powering a microprocessor as described in claim 282 further comprising a bypass capacitance adjacent said microprocessor.

288. A power supply circuit powering a microprocessor as described in claim 287 wherein said bypass capacitance comprises a total bypass capacitance selected from a group consisting of less than about .2 millifarads and less than about .5 millifarads.

289. A power supply circuit powering a microprocessor as described in claim 287 wherein said bypass capacitance comprises a capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

290. A power supply circuit powering a microprocessor as described in claim 282 wherein

said substantially inductive DC output comprises a substantially non-capacitive output.

291. A power supply circuit powering a microprocessor as described in claim 283 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

292. A power supply circuit powering a microprocessor as described in claim 283 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

293. A power supply circuit powering a microprocessor as described in claim 283 wherein said microprocessor comprises a microprocessor operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

294. A power supply circuit powering a microprocessor as described in claim 282 wherein said DC power supply comprises a voltage regulation module.

295. A method of powering a low voltage, high current microprocessor capable of a rapid current demand, comprising the steps of:

a. providing a DC power supply having a substantially inductive DC output; and
b. powering said microprocessor with said substantially inductive DC output.

296. A power supply circuit powering a low voltage, high current microprocessor capable of a rapid current demand comprising a voltage regulation module having a substantially non-capacitive DC output.

297. A power supply circuit powering a micropr essor as described in claim .. said microprocessor comprises a low volt. e, high current load and ... voltage regulation module provides a regul..d voltage to said load.

298. A power supply circuit powering a microproc.ssor as described in claim 296 where said voltage regulation module is physically emote from said microprocessor.

299. A power supply circuit powering a microprocessor as described in claim 298 wherein said voltage regulation module provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said voltage regulation module to said microprocessor, over at least about one inch from said voltage regulation module to said microprocessor, and over at least about two inches from said voltage regulation module to said microprocessor.

300. A power supply circuit powering a microprocessor as described in claim 296 wherein said voltage regulation module is electrically remote from said microprocessor.

301. A power supply circuit powering a microprocessor as described in claim 296 further comprising a bypass capacitance adjacent said microprocessor.

302. A power supply circuit powering a microprocessor as described in claim 301 wherein said bypass capacitance comprises a total bypass capacitance selected from a group consisting of less than about .2 millifarads and less than about .5 millifarads.

303. A power supply circuit powering a microprocessor as described in claim 301 wherein said bypass capacitance comprises a capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component. about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

304. A power supply circuit powering a microprocessor as described in claim 296 wherein said substantially non-capacitive DC output comprises a subtantially inductive DC output.

305. A power supply circuit powering a microprocessor as described in claim 304 wherein a subtantially inductive DC output comprises an inductance internal to said voltage regulation module.

306. A power supply circuit powering a microprocessor as described in claim 305 wherein said inductance internal to said voltage regulation module comprises an inductance selected from a group consisting of a total series inductance and an interconnect inductance.

307. A power supply circuit powering a microprocessor as described in claim 304 or 305 wherein said substantially inductive DC output comprises an inductance external to said voltage regulation module.

308. A power supply circuit powering a microprocessor as described in claim 297 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

309. A power supply circuit powering a microprocessor as described in claim 297 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

310. A power supply circuit powering a microprocessor as described in claim 297 wherein said microprocessor comprises a microprocessor operating at a maximum current

selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

311. A method of powering a low voltage, high current microprocessor capable of a rapid current demand, comprising the steps of:

a. providing a voltage regulation module having a substantially non-capacitive DC output; and

b. powering said microprocessor with said substantially non-capacitive DC output.

312. A power supply circuit powering a low voltage, high current microprocessor capable of a rapid current demand comprising a voltage regulation module having a substantially inductive DC output.

313. A power supply circuit powering a microprocessor as described in claim 312 wherein said microprocessor comprises a low voltage, high current load and wherein said voltage regulation module provides a regulated voltage to said load.

314. A power supply circuit powering a microprocessor as described in claim 312 wherein said voltage regulation module is physically remote from said microprocessor.

315. A power supply circuit powering a microprocessor as described in claim 314 wherein said voltage regulation module provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said voltage regulation module to said microprocessor, over at least about one inch from said voltage regulation module to said microprocessor, and over at least about two inches from said voltage regulation module to said microprocessor.

316. A power supply circuit powering a microprocessor as described in claim 312 wherein said voltage regulation module is electrically remote from said microprocessor.

317. A power supply circuit powering a microprocessor as described in claim 312 further

comprising a bypass capacitance adjacent said microprocessor.

318. A power supply circuit powering a microprocessor as described in claim 317 wherein said bypass capacitance comprises a total bypass capacitance selected from a group consisting of less than about .2 millifarads and less than about .5 millifarads.

319. A power supply circuit powering a microprocessor as described in claim 317 wherein said bypass capacitance comprises a capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

320. A power supply circuit powering a microprocessor as described in claim 312 wherein said substantially inductive DC output comprises a substantially non-capacitive DC output.

321. A power supply circuit powering a microprocessor as described in claims 312 wherein said substantially inductive DC output comprises an inductance internal to said voltage regulation module.

322. A power supply circuit powering a microprocessor as described in claim 321 wherein said inductance internal to said voltage regulation module comprises an inductance selected from a group consisting of a total series inductance and an interconnect inductance.

323. A power supply circuit powering a microprocessor as described in claims 312 or 321 wherein said substantially inductive DC output comprises an inductance external to said voltage regulation module.

324. A power supply circuit powering a microprocessor as described in claim 313 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting of less than about 2 volts. less than about 1.8 volts. less than about 1.5 volts. less than about 1.3 volts. less than about 1 volt. and less than about 0.4 volts.

325. A power supply circuit powering a microprocessor as described in claim 313 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond. at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond. at least about 3 amperes per nanosecond. at least about 10 amperes per nanosecond. and at least about 30 amperes per nanosecond.

326. A power supply circuit powering a microprocessor as described in claim 313 wherein said microprocessor comprises a microprocessor operating at a maximum current selected from a group consisting of more than about 15 amperes. more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

327. A method of powering a low voltage. high current microprocessor capable of a rapid current demand. comprising the steps of:

a. providing a voltage regulation module having a substantially inductive DC output; and

b. powering said microprocessor with said substantially inductive DC output.

328. A rectification circuit comprising:

a. a first rectifier element;

b. a second rectifier element;

c. a passive sinusoidal drive system to which said first rectifier element and said second rectifier element are responsive; and

d. a DC output responsive to said first rectifier element and said second rectifier element.

329. A rectification circuit as described in claim 328 and further comprising a synchronous rectifier control system to which said first and second rectifier elements are responsive.

330. A rectification circuit as described in claim 328 wherein said passive sinusoidal drive system comprises a gate drive transformer element.

331. A rectification circuit as described in claim 328 wherein said sinusoidal drive system to which said first and second rectifier elements are responsive comprises a high frequency sinusoidal drive system.

332. A rectification circuit as described in claim 331 wherein said high frequency sinusoidal drive system comprises a drive system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz. a frequency greater than at least about 500 kHz. a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ. a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second synchronous rectifier elements, and any permutations or combinations of the above.

333. A rectification circuit as described in claim 329 wherein said synchronous rectifier control system comprises a bias input.

334. A rectification circuit as described in claim 333 wherein said bias input comprises a DC input.

335. A rectification circuit as described in claim 333 wherein said bias input comprises a low frequency input.

336. A rectification circuit as described in claim 334 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said DC input.

337. A rectification circuit as described in claim 335 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said low frequency input.

338. A method of current rectification, comprising the steps of:

a. providing a first rectifier synchronous element and a second synchronous rectifier element;

b. providing an AC input to said first and second synchronous rectifier elements;

c. passively sinusoidally driving said first and said second synchronous rectifier elements; and

d. producing a DC output.

339. An AC to DC conversion system comprising:

a. an AC input:

b. a rectification circuit having a total capacitance; and

c. a DC output:

wherein said conversion system affirmatively utilizes said total capacitance of said rectification circuit.

340. An AC to DC conversion system as described in claim 339 wherein said rectification circuit comprises at least two rectifier elements.

341. An AC to DC conversion system as described in claim 340 wherein said at least two rectifier elements each comprise a Field Effect Transistor.

342. An AC to DC conversion system as described in claim 341 wherein said total capacitance of said rectification circuit comprises an adjunct drain-to-source capacitance of each Field Effect Transistor.

343. An AC to DC conversion system as described in claim 342 wherein said total capacitance of said rectification circuit further comprises circuit capacitance additional to said adjunct drain to source capacitance of each Field Effect Transistor.

344. An AC to DC conversion system as described in claim 340 wherein said at least two rectifier elements each comprise a synchronous rectifier element.

345. An AC to DC conversion system as described in claim 344 wherein said total capacitance of said rectification circuit comprises an adjunct capacitance of each synchronous rectifier element.

346. An AC to DC conversion system as described in claim 345 wherein said total capacitance of said rectification circuit further comprises circuit capacitance additional to said adjunct capacitance of each synchronous rectifier element.

347. An AC to DC conversion system as described in claim 345 wherein said conversion system affirmatively utilizes said adjunct capacitance of each said synchronous rectifier element to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

348. An AC to DC conversion system as described in claim 344 wherein said conversion system operates at a power conversion frequency and wherein said conversion system affirmatively utilizes said power conversion frequency to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

349. An AC to DC conversion system as described in claim 348 wherein said conversion system operates at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ.

350. An AC to DC conversion system as described in claim 344 and further comprising an overlapping conduction rectifier control system and wherein said conversion system affirmatively utilizes a conduction angle of each said synchronous rectifier element

to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

351. An AC to DC conversion system as described in claim 350 wherein said conduction angle of each of said at least two rectifier elements is selected from a group consisting of at least about 180 degrees. at least about 300 degrees, a conduction angle which creates a low rectifier RMS current. a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, and a conduction angle which creates a rectifier RMS current which is less than about 1.5 as compared to a DC output current.

352. An AC to DC conversion system as described in claim 344 and further comprising a transformer element and wherein said conversion system affirmatively utilizes a transformer leakage inductance of said transformer element to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

353. An AC to DC conversion system as described in claim 344 wherein said coversion system affirmatively coordinates a power conversion frequency of said conversion system, a conduction angle of each said synchronous rectifier element, a transformer leakage inductance of said conversion system, and said total capacitance to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

354. An AC to DC conversion system as described in claim 339 wherein said DC output powers a low voltage. high current component operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

355. An AC to DC conversion system as described in claim 339 wherein said DC output powers a low voltage, high current component capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

356. An AC to DC conversion system as described in claim 339 wherein said DC output powers a low voltage, high current component operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

357. A method of AC to DC conversion, comprising the steps of:

a. providing a rectification circuit having a total capacitance;

b. providing an AC input to said rectification circuit;

c. affirmatively utilizing said total capacitance of said rectification circuit; and

d. producing a DC output.

VII. ABSTRACT

Method and apparatus are disclosed for controlling the delivery of power to DC components such as computer components, microprocessors or the like. Designs of voltage regulation modules (112) are presented which are appropriate for faster components, lower voltages, and higher currents. Embodiments are especially suited to applications which cause rapid changes in the conductance of the load, even in the sub-microsecond time domain as is common in computer applications and the like and in powering electronics equipment, especially a distributed system and especially a system wherein low voltage at high current is required. Embodiments and sub elements provide energy storage for low voltage, high current electronic loads, an ability to supply current with rapid time variation, providing extremely low inductance connections, permitting VRM's (112) and the like to be located relatively remotely from the powered electronic load (186), and a steady voltage from a transformer isolated, high frequency AC to DC converter (102) under varying load without the necessity for feedback control, among other aspects.

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For: System for Controlling the Delivery of Power to DC Computer Components

Receiving Office: RO/US

Examiner: Berhane, A.

AMENDMENT UNDER ARTICLE 34

Pursuant to Article 34, the Applicant hereby requests that the Examining Authority amend four of the drawings in the referenced application.

This amendment is made to rectify obvious errors in the formal drawings. As required by PCT Rule 91.1, it should be understood that this amendment is authorized by Examiner Berhane, who has indicated that it will be entered to the extent permitted.

Accordingly, attached are replacement drawings sheets 24/34, 26/34, 27/34, 29/34 and this amendment. It is requested that the replacement drawings be made a part of the international application.

A. AMENDMENT

Please replace the four drawings pages: 24/34, 26/34, 27/34, 29/34, as previously submitted with the attached replacement pages 24/34, 26/34, 27/34, 29/34.

B. INDICATION OF DIFFERENCES

As required by Rule 66.8, and as set forth in paragraph 397 of the PCT Applicant's Guide, the following differences exist with respect to the drawings as originally filed:

The replacement drawing sheets make two changes to two of the figures provided as formal

drawings. These changes make the formal drawings comport with the priority case informal drawings originally filed in the case. Specifically:

a) in the figures listing circuit components, the sheets correct the value given for element C4 from 22 "PF" to 22 "uF". This erroneous letter is obvious from the original drawings.

b) in the figures showing circuitry, the sheets correct the wiring connecting one page to another. Again, this is obvious from the original drawings.

A copy of the corrected drawing sheets with the changes circled, and a copy of the priority case informal drawings with the areas of interest circled is also provided to simplify review. The priority case informal drawings show not only the wiring now provided but also that the capacitance value, 22, is in uF (microfarads) via the notation that unless otherwise specified, "2) ALL CAPACITANCE VALUES ARE IN MICROFARADS. 50V."

As can be understood, these errors accidentally occurred when the replacement formal drawings were submitted. They were not noticed by either the undersigned or the Receiving Office at that time and so accidentally were included in the case. It is requested that these amendment be entered to avoid permitting the case to contain a known inaccuracy or error.

C. CONCLUSION

The foregoing amendments do not go beyond the disclosure in the international application as filed. The applicant wishes to thank Examiner Berhane for his authorization and consideration of these amendments.

Dated this 23rd day of August, 2001.

Respectfully Submitted,
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SYSTEM FOR CONTROLLING THE DELIVERY OF POWER TO DC COMPUTER COMPONENTS

I. TECHNICAL FIELD

This invention is applicable for use in powering a wide variety of circuitry that requires low voltage and high current. In addition it provides capability to provide rapidly changing current. In particular it applies to microprocessors and similar circuitry especially where they are requiring less than 2 volts and are projected to require less than one volt.

Buck converter topologies are in current use for powering microprocessors. For a 2.5 volt, 13 ampere requirement, a switching frequency of 300 kHz is becoming inadequate. To meet substantial step load changes a large output capacitance is becoming required. As microprocessor voltage requirements move downward toward 1.0 volt at 50 amperes, the prior art topologies become even less suitable. With a drop in voltage (and an attendant drop in differential voltage tolerance) of 2.5 times, and an increase of current of 4 times, a larger output capacitor is now needed to maintain the required step response. It becomes increasingly difficult or impossible, however, to locate such a large capacitor close to the microprocessor connections. In addition, the cost of this approach increases with decreasing voltage. One solution to this problem has been to increase the frequency of the voltage regulation module. When the frequency increases in such an arrangement, however, the non-resonant edges of this waveform cause problems such as the commutation of FET output capacitance and prevent increasing the switching frequency above about a megahertz. This situation is rapidly becoming serious as microprocessors and other low voltage electronics are being developed which are increasingly difficult to provide suitable power for. The present invention permits the achievement of power for such needs. It permits higher frequencies and can be configured to handle higher currents.

This situation is rapidly becoming serious as microprocessors and other low voltage electronics are being developed which are increasingly difficult to provide suitable power for.

As mentioned, this invention specifically relates to powering computer systems. Here, often switch-mode DC is created to power the internal components of the system. It has particular applicability in new designs where microprocessors have high demands and power changes. Such can relate to the area of powering low voltage, high current electronics. As

mentioned, though, the invention is applicable in the field of computing, and much of the following description is presented in that context. It should be understood, however, that other embodiments are in no way limited to the field of computing, and are applicable to a wide variety of circumstances wherein a variety of power absorbing loads which absorb electrical power may abruptly change their power absorbing characteristics (that is to say, their impedance may undergo a rapid change). They are also applicable if such loads are separated physically such that the voltage which may be dropped across the dynamic impedance of the power carrying conductors is a significant fraction of the voltage delivered to such loads. They are also increasingly applicable to applications wherein design tradeoffs are forcing a steady decrease in operating voltages. Such situations may arise in telecommunications, radar systems, vehicle power systems and the like, as well as in computing systems. Further, the DC/AC converter itself may have applications in broader and other contexts as well.

II. BACKGROUND

The architecture of computing systems has undergone tremendous changes in the recent past, due principally to the advance of microcomputers from the original four-bit chips running at hundreds of kilohertz to the most modern 32 and 64 bit microprocessors running at hundreds of megahertz. As the chip designers push to higher and higher speeds, problems arise which relate to thermal issues. That is, as the speed of a circuit is increased, the internal logic switches must each discharge its surrounding capacitance that much faster. Since the energy stored in that capacitance is fixed (at a given voltage), as the speed is increased, that energy, which must be dissipated in the switches, is dumped into the switch that many more times per second. Since energy per second is defined as power, the power lost in the switches therefore increases directly with frequency.

On the other hand, the energy stored in a capacitance increases as the square of the voltage, so a capacitor charged to two volts will store only 44% of the energy stored in that same capacitor charged to three volts. For this reason, a microcomputer designed to operate at two volts will, when run at the same speed, dissipate much less power than the same microprocessor operating a three volts. So there is a tendency to lower the operating voltage of microprocessors.

Other considerations cause the microprocessor to exhibit a lower maximum speed if operated at a lower voltage as compared to a higher operating voltage. That is, if a circuit is operating at full speed, and the voltage on that circuit is simply reduced, the circuit will not operate properly, and the speed of the circuit (the "clock speed") may have to be reduced. To maintain full speed capability and still operate at lower voltage, the circuit often must be redesigned to a smaller physical size. Also, as the size of the circuitry is reduced, and layer thickness is also reduced, the operating voltage may need to be lowered to maintain adequate margin to avoid breakdown of insulating oxide layers in the devices. For the past few years, these steps have defined the course of microprocessor design. Key microprocessor designers, seeking the maximum speed for their products, have therefore expended considerable effort trading off the following considerations:

- higher speed chips are worth more money;
- higher speed chips must dissipate more heat;
- there are limitations to removal of that heat;
- lower voltages reduce the heat generated at a given speed; and
- smaller devices run faster at a given voltage.

Of course, there are many, many important trade-off considerations beyond these, but the above list gives the basic elements which relate to some aspects of the current invention. The result of these considerations has been for the microprocessor designers to produce designs that operate at lower and lower voltages. Early designs operated at five volts; this was reduced to 3.3. to 3.0, to 2.7, to 2.3, and at the time of writing the leading designs are operating at 2.0 volts. Further reductions are in store, and it is expected that future designs will be operated at 1.8, 1.5, 1.3, 1.0, and even below one volt, eventually perhaps as low as 0.4 volts.

Meanwhile, advances in heat removal are expected to permit processors to run at higher and higher heat dissipation levels. Early chips dissipated perhaps a watt; current designs operate at the 30 watt level, and future heat removal designs may be able to dissipate as much as 100 watts of power generated by the processor. Since the power dissipated is proportional to the square of the operating voltage, even as the ability to remove heat is improved, there remains a tendency to run at lower operating voltages.

All of this is driven by the fundamental consideration: higher speed chips are worth

more money. So the designers are driven to increase the speed by any and all means at their disposal, and this drives the size of the chips smaller, the voltages lower, and the power up. As the voltage drops the current increases for a given power, because power is voltage times current. If at the same time improvements in heat removal permit higher powers, the current increases still further. This means that the current is rising very rapidly. Early chips drew small fractions of an ampere of supply current to operate, current designs use up to 15-50 amperes, and future designs may use as much as 100 amperes or more.

As the speed of the processors increase, the dynamics of their power supply requirements also increase. A processor may be drawing very little current because it is idling, and then an event may occur (such as the arrival of a piece of key data from a memory element or a signal from an outside event) which causes the processor to suddenly start rapid computation. This can produce an abrupt change in the current drawn by the processor, which has serious electrical consequences.

Inductance is the measure of energy storage in magnetic fields. All current-carrying conductors have associated with their current a magnetic field, which represents energy storage. It is well known by workers in the art that the energy stored in a magnetic field is half the volume integral of the square of the magnetic field. Since the field is linearly related to the current in the conductor, it may be shown that the energy stored by a current carrying conductor is proportional to half the square of the current, and the constant of proportionality is called the "inductance" of the conductor. The energy stored in the system is supplied by the source of electrical current, and for a given power source there is a limit to the rate at which energy can be supplied, which means that the stored energy must be built up over time. Thus the presence of an energy storage mechanism naturally slows down a circuit, as the energy must be produced and metered into the magnetic field at some rate before the current can build up.

The available voltage, the inductance, and the rate of change of current in a conductor are related by the following equation, well known by those skilled in the art:

$$V = L * \partial I/\partial t$$, *where L is the inductance of the conductor, and ∂I/∂t is the rate of change of current in the conductor.*

This equation states that the voltage required to produce a given current change in a load on a power system increases as the time scale of that change is reduced, and also increases as the inductance of any connection to that load is increased. As the speed of microprocessors is increased, the time scale is reduced, and as the available voltage is reduced, this equation requires the inductance to be dropped proportionally.

Normally, in powering semiconductor devices one does not need to consider the inductance of the connections to the device, but with modern electronics, and especially with microprocessors, these considerations force a great deal of attention to be brought to lowering the inductance of the connections. At the current state of the art, for example, microprocessors operate at about two volts, and can tolerate a voltage transient on their supply lines of about 7%, or 140 millivolts. These same microprocessors can require that their supply current change at a rate of at least one-third or even nearly one ampere per nanosecond, or $3*10^8$ or 10^9 amperes/second, respectively. The above equation indicates that an inductance of about 140 picohenries ($1.4*10^{-10}$ H) and ½ nanohenry, ($5*10^{-10}$ H) will drop a voltage of 140 millivolts at these two rates of current rise. To put this number in perspective, the inductance of a wire one inch in length in free space is approximately 20 nanohenries, or 20,000 picohenries. While the inductance of a connection can be reduced by paralleling redundant connections, to create a connection with an inductance of 140 picohenries with conductors about a centimeter long would require some 20 parallel conductors, and for instance a connection with an inductance of ½ nanohenry would require nearly 100 parallel conductors.

The foregoing discussion implies that the source of low voltage must be physically close to the microprocessor, or more generally the active portion of a particular component, which in turn implies that it be physically small. While it might be suggested that capacitors might be used to supply energy during the delay interval required for the current in the conductors to rise, the intrinsic inductance of the connections to the capacitors currently severely limits this approach. So the system designer is faced with placing the source of power very close to the processor to ensure that the processor's power source is adequately stable under rapid changes in current draw. This requirement will become increasingly severe as the voltages drop still further and the currents increase, because the former reduces the allowable transient size and the latter increases the potential rate of change of current. Both

factors reduce the permissible inductance of the connection. This can force the designer to use smaller capacitors which have low inductance connections, and because the smaller capacitors store less energy, this drives the power system to higher frequencies, which adds costs and lowers efficiency.

The foregoing remarks are not limited in computers to the actual central microprocessor. Other elements of a modern computer, such as memory management circuits, graphic display devices, high speed input output circuitry and other such ancillary circuitry have been increased in speed nearly as rapidly as the central processing element, and the same considerations apply.

Many modern electronics circuitry, including computers, are powered by switchmode power conversion systems. Such a system converts incoming power from the utility line to the voltages and currents required by the electronic circuitry by operation of one or more switches. In low power business and consumer electronics, such as desktop personal computers, the incoming power is supplied as an alternating voltage, generally 115 volts in the United States, and 220 volts in much of the rest of the world. The frequency of alternation is either 50 or 60 Hertz, depending upon location. Such utility power must be converted to low voltage steady (direct) current, or dc, and regulated to a few percent in order to be useful as power for the electronic circuits. The device which performs such conversion is called a "power supply". While it is possible to create a low voltage regulated DCpower source using simple transformers, rectifiers, and linear regulators, such units would be heavy, bulky and inefficient. In these applications it is desirable to reduce weight and size, and this approach is unsuitable for this reason alone. In addition, the inefficiency of linear regulators is also unacceptable. Efficiency is defined as the ratio of output power to input power, and a low efficiency implies that heat is being developed in the unit which must be transferred to the environment to keep the unit cool. The lower the efficiency the more heat must be transferred, and this is itself a reason for finding an alternate approach.

For these reasons, virtually all modern electronics circuitry is powered by switchmode conversion systems. These systems typically operate as follows. The incoming utility power is first converted to unregulated direct current by a rectifier. The rectified DCis then converted to a higher frequency, typically hundreds of kilohertz, by electronic switches. This higher frequency power is then transformed by a suitable transformer to the appropriate

voltage level; this transformer also provides isolation from the utility power, required for safety reasons. The resulting isolated higher frequency power is then rectified again, and filtered into steady direct current for use by the electronics. Regulation of the output voltage is usually accomplished by control of the conduction period of the electronic switches. The resulting power conversion unit is smaller and lighter in weight than earlier approaches because the size and weight of the transformer and output filter are reduced proportionally to the increase in frequency over the basic utility power frequency. All of this is well known in the prior art.

In a complex electronic system, various voltages may be required. For example, in a computer system the peripherals (such as disk drives) may require +12 volts, some logic circuits may require +5 volts, input/output circuits may additionally require -12 volts, memory interface and general logic may require 3.3 volts, and the central microprocessor may require 2 volts. Standards have developed so that the central power source (the device that is connected directly to the utility power) delivers ±12 and +5 volts, and the lower voltages are derived from the +5 supply line by additional circuitry, called voltage regulation modules, or VRMs, near to the circuits that require the lower voltage. These additional circuits convert the +5 volt supply to high frequency AC power again, modifying the voltage through control of the period of the AC power, and again re-rectifying to the lower voltage dc.

The resulting overall system is complex and not very efficient, in spite of the use of switchmode technology. In a typical 200 watt computer system, four watts are lost in the initial rectification of the utility line, eight watts in the electronic switches, 2.5 watts in the transformer, 20 watts in the output rectification and filtering, and four watts in the connections between the center power supply and the electronics boards. Thus 38.5 watts are lost in the conversion process for the higher voltage electronic loads. Substantial additional losses may be sustained in the low voltage conversion process. A typical 50 watt voltage regulation module, which may convert +5 volts at 10 amperes to +2 volts at 25 amperes for the microprocessor, will itself have losses of about one watt each in the AC conversion and transformer, and ten watts in the final rectification and filtering. Other voltage regulation modules will have losses almost as great, resulting in losses for the entire system which may be one-third of the power used. Some particularly inefficient approaches may demonstrate efficiencies as low as 50%, requiring that the input power circuits utilize twice the power

required by the actual final circuitry, and requiring that twice the heat be dissipated in the electronics (which must be removed by a fan) as is theoretically required by the actual operating circuitry.

This system evolved over the years and is not optimum for many current uses, but persists because of inertia of the industry and because of the perceived benefit of maintaining industry standards on voltages and currents as generated by the central power unit.

An analysis of current trends in the microprocessor industry clearly indicates that the current system will not be adequate for the future. These trends show that the current draw of critical elements such as the core microprocessor has been steadily increasing and will continue to do so into the future. Meanwhile, the operating voltage has been steadily decreasing, dropping with it the allowable tolerance of the supply voltage in absolute terms. Finally, the rate of change of processor current - the current slew rate - is increasing very rapidly, with substantial additional increases forecast for the near future. All of these factors mitigate against the current technology and require a new approach to be adopted in the future. It has been reliably estimated that the current powering and other technology will not last more than one additional generation of microprocessors, and since designers are currently at work on the generation following the next, it can be said that these designers are in the process of developing a microprocessor which cannot be powered by currently available technology.

A further problem in the prior art is the use of square wave electronic conversion techniques. Such technology, known as PWM, for Pulse Width Modulation, produces switch voltage waveforms which have steeply rising edges. These edges produce high frequency power components which can be conducted or radiated to adjacent circuitry, interfering with their proper operation. These high frequency power components may also be conducted or radiated to other electronic equipment such as radio or television receivers, also interfering with their proper operation. The presence of such components requires careful design of the packaging of the power system to shield other circuitry from the high frequency power components, and the installation of expensive and complex filters to prevent conduction of these components out of the power supply package on its input and output leads. What is needed then, is a power conversion system which enables small, highly efficient voltage regulation modules to be placed close to the point of power use, which is fast overall, and

which is itself efficient and at least as low in cost as the prior art technology it replaces.

III. DISCLOSURE OF INVENTION

It is an object of the present invention, therefore, to provide a means for storing energy with lower inductance connections than could be achieved with the prior art. It is a further object of the present invention to provide a source of energy at low voltage and high current which does not need to be placed in very close proximity to the electronic load. Similarly, it is yet an another object of the invention to provide a source of low voltage which can sustain the voltage across the powered load even in the presence of high rates of change of current draw

It is also an object of the present invention, to provide a means of converting utility power to high frequency alternating power for efficient distribution at higher efficiency than can be achieved using existing techniques. It is also an object to provide a means of converting high frequency AC power to the low DCvoltages and high DCcurrents required by current and future electronics at higher efficiency than can be achieved using current techniques. It is another object of the present invention to maintain that efficiency over a wide range of load conditions.

A further object of the present invention is to provide a source of high frequency power which is substantially smaller than that of the prior art. Similarly it is an object to provide a source of low voltage at high current which is substantially smaller than that of the prior art to permit such a source to be placed in very close proximity to the electronic load.

It is also an object of the preset invention to provide closer control of the output voltage of a power source, even for extremely short time periods. That is to say, it is an object to ease the task of the powering or of providing a power source so that it does not need such wide bandwidth and has a small transient response to changes in load. Thus an object is to provide a system with better transient response to changes in load.

It is a further object of the invention to provide a power conversion system which stores less energy than that required by the prior art.

It is additionally an object of the present invention to provide a power conversion system which can be produced at lower cost than the prior art.

It is also an object to address problems associated with the use of square wave

electronic conversion techniques. It is yet another object of the invention to reduce possible interference between the power system and the electronics being powered, as well as with other devices in the vicinity of the powered electronics, by reducing the rate of rise of currents and the rate of fall of voltages in the power system. Similarly, an object is to provide power using smoothly varying waveforms in the power conversion circuitry.

It yet a further object of one embodiment of the present invention provide to power with the aforesaid objects being satisfied, yet operate at either a constant frequency or, through other embodiments, to accommodate variable frequencies as well.

Another fundamental aspect of the invention is the potential for the affirmative use of the transformer leakage inductance. This can be necessary as the DC output voltage requirement is lowered.

Another benefit of this invention involves the very nature of a power source. By incorporating some or all these elements it can be possible to provide power remotely. By making the output capacitance consist of only the bypass capacitors necessary on the microprocessor pins, the circuit feeding the microprocessor assembly can have essentially an inductive output.

Several features will be disclosed which taken together or separately can allow the power conversion frequency to be increased to provide a low stored energy approach to meet the high di/dt requirements for next generation low voltage requirements. Thus, yet other objects include providing a circuit and method for providing power to electronics with low voltage, high current and high di/dt requirements, providing substantially higher power conversion frequencies, providing a circuit which allows a reasonable amount of transformer leakage inductance and switching device capacitances, providing a circuit or method whereby the synchronous rectifiers (SR's) always switch with zero voltage across the device, allowing high frequency operation, providing a circuit or method whereby the control signal to the SR operates in a non-dissipative fashion, allowing HF operation, and providing a reduced size of the output capacitance through HF operation.

Accordingly, in one embodiment the present invention is directed to a system of energy storage which can store more energy and be placed physically farther from the powered electronics, through the reduction of magnetic fields surrounding the electrical connections and the magnetic energy stored therein, thereby creating a faster responding

storage and powering medium. The reduction of the magnetic fields and the resulting reduction of inductance permits electronics to operate at higher speed, and the increased energy storage permits the powering system to operate at lower speed. This reduction in powering system frequency may permit lower costs than could be obtained using high frequency power systems.

Similarly, the present invention in another embodiment is directed to a system of power conversion which eliminates many of the elements of the prior art, by distributing high frequency AC power to a point near the loads, and performing a single conversion from AC to DC at the point of power consumption. In particular, the present invention addresses this latterAC toDC conversion and solution of the problems related to conversion of higher voltage AC power to very low DCvoltages with good regulation and transient response.

The elimination of many of the redundant elements in the prior art approach not only increases efficiency by eliminating a power loss element, but also reduces cost by elimination of the cost of the elements removed from the system. The reduction of frequency also increases the efficiency of the powering system, because at higher frequencies switching losses become increasingly important and may equal or exceed all other losses. The present invention accomplishes many of these objects by providing a low inductance connection for energy storage elements which is not limited in length through the mechanism of reducing the volume of the magnetic field surrounding the conductors intermediate to the energy storage element and the powered electronics.

In yet another embodiment, the present invention distributes high frequency smoothly varying or even sinusoidal waveforms, which exhibit relatively low rates of voltage change for a given frequency, and much lower than alternative AC approaches, such as distribution of square wave or trapezoidal waveforms. The distribution of sinusoidal AC voltage, rather than DCvoltages as is usually done in the prior art, not only simplifies the central power unit, but also greatly simplifies the voltage regulation modules, reducing cost and raising efficiency. This approach also results in greatly reduced interference between the power unit and adjacent circuitry, and simplifies the design and reduces the cost of the line filters used to avoid conducted interference along the utility power lines. Also, distribution of low DCvoltages (e.g., 5 volts) results in relatively higher losses in the distribution wires and connectors when compared to the use of medium voltage alternating distribution levels (e.g.,

30 volts rms), which nevertheless remain safe to touch.

IV. BRIEF DESCRIPTION OF DRAWINGS

Figure 1-1 shows a conventional computer power delivery system of the prior art.

Figure 1-2 is a more detailed depiction of a computer power delivery system of the prior art.

Figure 1-3 indicates the parts of the computer power delivery system of the prior art that may be eliminated by the present invention.

Figure 1-4 shows a computer power delivery system according to one embodiment of the present invention.

Figure 1-5 indicates an embodiment of the power conversion element of the present invention.

Figure 1-6 depicts another embodiment of the power conversion element of the present invention.

Figure 1-7 shows details of a switch drive according to the present invention.

Figure 1-8 shows a rectifier circuit of the present invention.

Figure 1-9 shows a variation of output voltage with changes in the value of a capacitance in one embodiment.

Figures 1-10 and 1-11 show two variations of the voltage across a load resistance as a function of the load resistance.

Figure 1-12 shows another embodiment with a two switch configuration and various general elements.

Figures 1-13 and 1-14 are plots of voltage waveforms at various locations for two different loads, high and low respectively.

Figure 3-1 shows a traditional buck converter of the prior art.

Figure 3-2 shows a waveform of the center point of the buck converter shown in Figure 3-1.

Figure 3-3 shows an embodiment of a transformer and rectifier portion according to the present invention.

Figure 3-4 shows the voltage waveforms as they may exist at various locations in the circuit shown in Figure 3-3.

Figure 3-5 shows one gate drive embodiment for the SR's according to the present invention.

Figure 3-6 shows a circuit for voltage control on the primary side with a single switching design.

Figure 3-7 shows a family of drain to source voltages as a function of the control input voltage across the FET.

Figure 3-8 shows a circuit for voltage control on the primary side with a dual switching design.

Figures 3-9 a, b, c & d shows various synchronous rectification circuits according to the invention.

Figure 3-10 shows a bulk capacitor and a by pass capacitor arrangement as applied to a microprocessor system in the prior art.

Figure 3-11 shows an overall preferred embodiment of the invention using a single switch control element.

Figure 3-12 shows an overall preferred embodiment of the invention using a dual switch control element.

Figure 3-13 shows an overall preferred embodiment of important aspects of the aspect of the design.

Figure 3-14 shows yet another preferred embodiment of a voltage regulation module design using a variable capacitor for primary side regulation.

Figure 3-15 is a Smith chart showing a range of VRM input impedances vs load current percentage for one design of the present invention.

V. MODE(S) FOR CARRYING OUT THE INVENTION

As can be easily understood, the basic concepts of the present invention may be embodied in a variety of ways. These concepts involve both processes or methods as well as devices to or which accomplish such. In addition, while some specific circuitry is disclosed, it should be understood that these not only accomplish certain methods but also can be varied in a number of ways. Importantly, as to all of the foregoing, all of these facets should be understood to be encompassed by this disclosure.

In the prior art, the central power supply provides several standard voltages for use by

the electronics. Referring to Figure 1-1, utility power (101), typically at 110 or 220 volt nominal AC power alternating at 50 or 60 cycles, is converted by power supply (106) to standard DCvoltages, usually ±12 and +5 volts. These voltages are brought out of the power supply on flying leads, which form a kind of distribution system (107), terminated in one or more connectors (108) These standard voltages are useful directly for powering most of the input/output circuitry (140) and peripherals (144), such as a hard disc, floppy disc, and compact disc drives. As the technology of central processing unit (CPU) chip (141) has advanced, as discussed above, the operating voltage of such chips has steadily been reduced in the quest for higher and higher operating speeds. This increase in processor speed eventually required an increase in speed of the dynamic random access memory (DRAM) chips (143) used to hold instructions and data for the CPU, and as a result the operating voltage of these DRAM chips has also been reduced. Also, not all of the logic required to manage the input/output functions and particularly the flow of data to and from the CPU and the memory and external devices is present on the CPU chip. These management functions, along with housekeeping functions (such as clock generation), interrupt request handling, etc., can be dealt with by the "chip set", shown in Figure 1-1 as logic management circuits (145). These circuits also have steadily increased in speed and have correspondingly required lower operating voltages.

The standard voltages are thus too high to properly power CPU (141), memory (143), and management circuits (145). These may all require different voltages, as shown in Figure 1-1, where the actual voltages shown are representative only. These different voltages may each be created by an individual Voltage Regulation Module (112) (VRM), which may reduce the voltage supplied by the power supply (106) to the voltage required by the powered circuitry.

From an overall point of view, the prior art process of delivering power to a circuit load such as CPU (141) involves all of the power processing internal to power supply (106), distribution system (107) and connectors (108), and the power processing internal to VRM unit (112). This overall process is shown in Figure 1-2. Central power supply (106), also called the "silver box", uses switchmode technology, with processing elements (102), (103), (104), and (105). The voltage regulation module (VRM) also uses switchmode technology. It should be understood that the discussion provided applies to both components. Thus the

various features discussed in one context should be understood as potentially being applicable to the other. Focusing upon the silver box design only for purposes of initial understanding, it can be understood that utility power (101) enters the silver box and is converted to unregulated DCpower by rectifier unit, or AC/DC converter (102). The resulting DCpower is then re-converted to alternating current power at a higher frequency by inverter unit (103) (also called a DC/AC converter). The higher frequency AC is galvanically connected to and is at the voltage level of utility power (101). Safety considerations require isolation from utility power (101), and as the required output voltage is much lower than that of utility power (101), voltage reduction is also needed. Both of these functions are accomplished by transformer (104). The resulting isolated, low voltage AC is then rectified to direct or multiply direct current power output(s) by rectifier and filter unit (105), distributed to the circuitry loads by distribution wiring (107) and connectors (108). As mentioned before, specific standard voltages ±12 and +5 volts must be converted to lower voltages for CPU (141), memory (143) and management logic (145), by VRM unit (112). The standard DCvoltage from power supply unit (106) (usually +5 volts) is converted to alternating power again by DC/AC converter (109), transformed to the lower voltage by transformer (110), and re-rectified to the proper low voltage by AC/DC unit (111).

As the voltage of the delivered power to the circuit load is decreased, the current increases, and as the speed of CPU (141) is increased, the power system must be able to handle larger and larger rates of change of current as well. As discussed above, this requires the source of power, which for CPU unit (141) (and other low voltage circuits) is VRM (112), to be close to the circuit load. While for the near term designs the rate of change of current can be handled by capacitive energy storage, for future designs at still lower voltages and higher currents VRM unit (112) must be made extraordinarily small so that it can be placed close to its circuit load, and also must operate at a very high frequency so that large amounts of energy storage are not required. The requirement for low energy storage is rooted in the two facts that there is no physical room for the larger storage elements and no tolerance for their higher intrinsic inductance. Thus a requirement emerges that the frequency of VRM (112) must be increased.

Further, a glance at Figure 1-2 indicates at least two redundant elements which can be eliminated. The established policy of distributing direct current power requires rectifier and

filter (105), and the need for dropping the voltage to lower levels requires re-conversion of the DCto alternating current power by inverter (109). One of these is clearly redundant.

This opens the possibility of reduction of cost by eliminating elements (105) and (109), and choosing to distribute alternating current power instead of direct current power. Of course, the AC improvement may also be configured with existing, traditional DCleads as well in a hybrid system if desired. Returning to the improvement, however, as mentioned before, the frequency of inverter (109) has had to increase and will continue to increase, which requires, in the reduced system, that the frequency of inverter (103) be increased to a level adequate to serve the future needs of the system. Figure 1-3 indicates these redundant elements.

Another redundancy exists in principle, between transformers (104) and (110), but the desire to provide isolated power in the distribution system (107) mandates the use of transformer (104), and the requirement for different voltages for the different loads may also require the various VRMs to utilize transformer (110). Assuming that these elements are left in place, then, the use of high frequency AC distribution produces a system as shown in Figure 1-4. Thus one embodiment is directed specifically to the simplified VRM. Such an arrangement also permits electrically remote location of power element (e.g. at locations where the lead inductance would have otherwise have come into play using the prior techniques).

In Figure 1-4, central power supply (147) converts utility power (101) to DCpower by AC/DC converter (146). This DCpower is then converted to high frequency sinusoidal power by DC/AC converter (113). The sinusoidal power (or perhaps "substantially" or "approximately" sinusoidal power, as may be produced by even a less than ideal inverter or the like) is distributed to the location of use of the power, where high frequency VRMs (118) convert the sinusoidal power to low voltage, high current power for the circuit loads such as CPU (141), input/output circuits (140), logic management circuits (145), and memory (143). In this approach, a VRM is required not only for the aforementioned low voltage circuits, but also for peripherals (144), since the DC power (likely +12 volt) requirement for these units is not supplied by the central power supply (106). (Note, the central power supply (106) may supply only sinusoidal high frequency AC power in this approach). High Frequency Transformer (114) may thus provide galvanic isolation and may transform the

voltage from constant voltage Sinusoidal DC/AC Converter (113) to a level considered safe to touch.

It is possible to organize a distribution system which provides a constant current to the totality of the loads, or alternatively to provide a constant voltage to those loads. The architecture of computer systems and other complex electronic systems with loads which require multiple voltages is more suited to the latter approach. That is, it is desirable that the magnitude of the distributed AC voltage be maintained very close to constant against any output load variation, even on a microsecond time scale. Thus, it can accommodate a variable load, namely a load which alters at levels which would have caused variation in the power supplied in arrangements of the prior art. It may also be important to keep the Total Harmonic Distortion (THD) of the distributed AC voltage low, to reduce Electro-Magnetic Interference (EMI). It should be noted, however, that the present invention may be modified to provide a constant current as well. That is, as those of ordinary skill in the art would readily understand, it is possible to modify the described circuit so that a constant current is delivered into a load which varies from nominal to a short circuit, for use in constant current applications.

Converter (113) may be designed to provide a constant output voltage with low THD, independent of load. Some of the embodiments presented herein depend upon being supplied with a constant input DCvoltage from converter (146). It would of course also be possible to create this constant distribution voltage by feedback internal to converter (113), as an alternative, which then would not require a constant input voltage from converter (146). The latter approach - creating constant voltage through feedback - requires that the feedback system have very high bandwidth (high speed) in order to maintain the output voltage very close to constant against any output load variation, even on a nanosecond time scale. This feedback approach may be difficult and expensive to achieve, and the present invention is directed to accomplishing a constant voltage from converter (113) by the intrinsic operation of the circuit, without feedback. This can be significant because it can satisfy the needs of a system which has rapid energy demands such as a rapid current demand of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and even at least about 30 amperes per nanosecond and beyond. It also can be

significant because it can permit reaction to a change in conditions very quickly, such as within:

- less than about a period of a "Nyquist frequency" (e.g. the Nyquist rate, that is the maximum theoretical rate at which sampling or transmission of an event can occur for a feedback-type of system),
- less than about two and a half times a period of a Nyquist frequency,
- less than about five times a period of a Nyquist frequency,
- less than about ten times a period of a Nyquist frequency,
- less than about twice a period of said alternating power output,
- less than about four times a period of said alternating power output,
- less than about 200 nanoseconds,
- less than about 500 nanoseconds,
- less than about 1000 nanoseconds, and
- less than about 2000 nanoseconds.

Figure 1-5 shows one embodiment of a constant voltage high frequency power source to accomplish the function of converter (113). Here DCpower source (119) is the circuit representation of the constant voltage from converter (146), and load (128) represents the constellation of loads connected to distribution system (115) (including the effects of connectors (18) and distribution system) (115). The voltage from source (119) is converted to a constant current by inductor (120) and either shunted by switch (122) when the switch is ON, or permitted to flow into network (148), comprising the elements in parallel with switch (122) when the switch is OFF. The network thus acts as a response network, that is, one which acts after the switch has transitioned. The voltage across switch (122) is approximately zero when switch (122) is ON and is dependent upon the response of network (148) when switch (122) is OFF. This response waveform, or "switch voltage waveform" is transformed by network (48) to form the voltage across load (128). It turns out to be possible to choose the values of elements (123), (124), (125), (126), and (127) such that the switch voltage is zero at the commencement of the interval of time when switch (122) is ON, independent of the value of the conductance of load (128), at least within a nominal range of conductance for load (128). This may be accomplished in the following way. If the conductance of load (128) is very small (light loading), little current will flow in inductance

(127), and its value will not strongly affect the waveform across switch (122). Then the values of elements (123), (124), (125), and (126) may be chosen to cause the waveform across switch (122) to be approximately zero, or to be a desired fixed value, at the moment when switch (122) begins to conduct. Clear descriptions for the methodology for accomplishing this may be found in U.S. patents 3,919,656 and 5,187,580. Once this has been accomplished, the conductance of load (128) may be changed to the maximum nominal value, and the value of inductor (127) chosen to return the value of voltage across switch (122)at the commencement of its ON period to the value chosen in the first step. This algorithm will result in a circuit for which the value of the switch voltage waveform at the commencement of the ON period of switch (122) is nearly independent of the value of the conductance of load (128), within the defined nominal range. It also results in a circuit for which the shape of the switch voltage waveform varies minimally over the range of the conductance of load (128). A significant function of the network formed by elements (123), (124), (125), (126), and (127) is to form a sinusoidal waveform across load (128). Since this is a linear passive network, namely, a network with no active elements (including but not limited to steering diodes, diodes generally, other active elements, or the like) or a network without some type of feedback element (an element which senses a condition and then responds to that condition as a result of a delayed decision-type of result), if the shape of the switch voltage waveform does not change in any substantial way, and especially if the fundamental frequency component of the switch voltage waveform (the Fourier component of the waveform at the operating frequency) does not change substantially, for this circuit the value of the sinusoidal voltage across load (128) will not change substantially. Thus selection of the values of elements (123), (124), (125), (126), and (127) in this manner results in a stable, constant, high frequency, pure sinusoidal voltage across load (128), independent of the value of the conductance of load (128), thereby accomplishing the objective of providing a constant voltage to the distribution system. It should be noted that the operation of this network to produce a constant output voltage is very fast; abrupt changes in the conductance of load (128) anywhere over its entire nominal range may be corrected in a few cycles of operation. This is much faster than typical feedback approaches could make the same correction and serves to provide a fast acting network, namely one which does not suffer the existing delay in a feedback type of system.

A unique element of the invention is its high efficiency over the entire load range from a nominal load to an open circuit or from a nominal load to a short circuit. (As one skilled in the art should understand, one way to achieve one as opposed to the other simply involves altering the AC distribution system by one-quarter wavelength.) This comes about largely as a result of the constant switch waveform described above. Since the voltage waveform changes but little over the load range, switching losses in the circuit are not affected by load variations. It should also be noted that all of the benefits of this invention are obtained without changing the frequency of operation. Thus, high efficiencies such as at least about 80%, at least about 85%, at least about 90%, at least about 95%, at least about 98% and even at least about 99% efficiency and beyond can be attained.

Such a circuit, which provides a constant voltage sinusoidal output across a load (or even in not strictly "across" the load, more generically "to which the load is responsive" thus encompassing bit direct and indirect responsiveness) which can vary at high speed, utilizing a single or multiple switch and a simple circuit, operating at constant frequency, while maintaining high efficiency over the entire load range, is a unique aspect of this invention in the field of power conversion.

Another unique element of the invention is in the nature of the method of driving switch (122). As has been pointed out previously, efficiency is important in these applications, and it is desirable not to waste energy anywhere, including the circuit used to drive switch (122). It is in the nature of high frequency switches such as Field Effect Transistors (FETs) that they have a large input capacitance. Circuits which change the voltage on the gate terminal in a square-wave manner must first charge that capacitance to a voltage well above the gate threshold voltage for switch (122), turning ON the FET, and in the process deposit energy into that capacitance. It must then discharge that capacitance to a voltage well below the gate threshold voltage for switch (122), in the process absorbing the energy stored in the gate capacitance. The power lost in the process is the energy stored in the gate capacitance, multiplied by the frequency of operation, and this can be a substantial number. In the present invention this loss is avoided by affirmatively utilizing the gate capacitance of switch (122), thus coordinating the circuitry to the gate or capacitance. That is, the energy stored in the gate capacitance during the period switch (122) is ON is, in the present invention, stored in another element of the system during the period switch (122) is

OFF, and is thereby available on the next cycle to return the gate above the threshold voltage for the next ON period. This may be accomplished by "resonating" the gate capacitance (or the effective capacitance of the system) with a series or parallel inductor. The entire system may be tuned to coordinate with the frequency of the output and the output capacitance of the switch. Referring to Figure 1-7, FET switch (122) is depicted as an internal switch device (139) with an explicit gate capacitance (138), shown separately. Gate drive circuit (121), according to the current invention, contains inductor (136) connected in series (or in parallel as shown in the dotted-line alternate connection) (137) which is selected such that the reactance of inductor (136) or (137) is equal to the reactance of capacitor (138) at the frequency of operation. In this way the energy in the gate system is transferred from gate capacitor (138) to inductor (136) (or its alternate) (137) and back again each cycle, and only the inevitable losses in the inductor and gate resistance need to be regenerated for each cycle.

In such a system the gate voltage is substantially sinusoidal. It will be obvious to those skilled in the art that the duty cycle of the system (that is, the fraction of the total period that switch (122) is ON) is determined by the fraction of the sinusoidal cycle which is substantially above the threshold voltage of switch (122). It will also be obvious that, while the duty cycle of switch (122) may be controlled by the magnitude of the sinusoidal signal, such an approach places limits on the available range of duty cycle, and also may result in longer than desirable commutation times (that is, the fraction of the total period during which the switch is transitioning from the ON to the OFF state), which may increase the losses of switch (122) and thereby reduce the efficiency of the system. For this reason, the drive waveform for switch (122) may be divided in the present invention into an AC portion (149) and a DCportion (150), and variation in the duty cycle of switch (122) may be controlled by varying the relative magnitude of the AC and DCcomponents of the drive waveform for switch (122).

An alternative approach to constant voltage, high frequency power generation is shown in Figure 1-6. Here again, DCpower source (119) is the circuit representation of the constant voltage from converter (146), and load (128) represents the constellation of loads connected to distribution system (115) (including the effects of connectors (108) and distribution system) (115). Switch (122) is placed in series with inductor (129), across source (119). The voltage across inductor (129) is transformed by transformer (131) and placed

across the network comprised of elements (132), (133), (134), and (135). This network produces the output voltage appearing across load (128), which again represents the constellation of loads connected to distribution system (115) (including the effects of connectors (108) and distribution system) (115). Provided the values of the circuit elements are properly chosen, this output voltage will be independent of the value of the conductance of load (128), within a nominal range of such conductance. To create this independence, it is sufficient to select the values of the elements such that, as one example, the reactance of inductor (129) in parallel with the magnetizing inductance of transformer (131) is equal to the reactance of capacitor (130) in parallel with the adjunct output capacitance of switch (122) at the frequency of operation, the reactance of inductor (132) in series with the leakage inductance of transformer (131) is equal to the reactance of capacitor (133) at the frequency of operation; and the reactance of inductor (134) is equal to the reactance of capacitor (35) at the frequency of operation. Selection of the values of the circuit elements in this manner will result in a stable, constant, high frequency, pure sinusoidal voltage across load (128), independent of the value of the conductance of load (128), thereby accomplishing the objective of providing a constant voltage to the distribution system.

The necessity for the parallel resonant circuit formed by inductor (134) and capacitor (135) is reduced if the minimum load conductance is not too close to zero. That is, the network comprised of elements (134) and (135) has the function of providing a minimum load to the generator so that the output waveform remains sinusoidal when load (128) is removed or reduced to a very low value. Should the application to which the invention is applied not present a load variation down to low values, or if the requirement for low THD not be present at light loads, the network comprised of elements (134) and (135) may be dispensed with. Alternatively, the network comprised of elements (134) and (135) may be reduced to a single element, which may be either an inductor or a capacitor, if the highest efficiency is not demanded.

It is generally possible to also dispense with inductor (129) by affirmatively utilizing the magnetization inductance of transformer (131). Similarly, it is generally possible to dispense with inductor (132) by affirmatively utilizing the leakage inductance of transformer (131). This may be accomplished through the modification of the construction of transformer (131) in the manner well known to those skilled in the art.

As before, to attain high efficiency it is important to affirmatively utilize the gate capacitance of switch (122), and all the remarks made above in reference to Figure 1-7 apply to the embodiment of Figure 1-6 as well.

As mentioned earlier, and referring to Figure 1-4, converter 113, operating together with AC/DC element (146), is designed to provide a constant high frequency AC output voltage with low THD, independent of load. It is VRM (118) which must convert this high frequency AC power from power unit (147) to low voltage high current DC power for use by the powered circuitry (145), (141), and (143). Figure 1-8 shows one embodiment of the rectifier portion of one embodiment of a VRM to accomplish this conversion in accordance with the present invention. Input AC power from power unit (147) may also be processed further to enhance its stability before the rectification process, and this further processing is not shown in Figure 1-4. The result of this processing is a stable regulated AC input (177) to the rectifier circuit (178) shown in the dotted box in Figure 1-8.

Rectifier circuit (178) is comprised of transformer (179), which in practice will exhibit leakage inductance caused by imperfect coupling between its primary and secondary windings. This leakage inductance may be represented in general as an inductance in series with the primary or secondary of the transformer. In Figure 1-8, it is represented by inductor (180), which therefore may not be an actual component in the circuit, but rather simply a circuit representation of part of the real transformer (179), as built. It should be noted that, should the natural leakage inductance of transformer (179) be smaller than desirable for any reason, additional inductance may be added in series with its secondary (or primary) to increase the natural value, as will be understood by those skilled in the art. For the purposes of this disclosure, inductor (180) may be considered to be the total of the natural leakage inductance of transformer (179) and any additional discrete inductance which may have been added for any purpose.

Diodes (83)rectify the AC output of transformer (179), and filter inductors (184) and filter capacitor (185) create a steady DCoutput for consumption by the microprocessor or other electronic load (186). For small output voltages, the voltage drop across the diodes (183) is too large relative to the output voltage, resulting in loss of efficiency. As a result diodes (183) may be profitably replaced by field effect transistor (FET) switches, which can be manufactured to have a much lower voltage drop. In this case the FET devices require a

drive signal to determine their conduction period; the circuitry to do this is not shown in Figure 1-8.

A second problem which arises as the output voltage is dropped is the intrinsic leakage inductance of transformer (179). This inductance, which, together with other circuit inductance, is represented as inductor (180), and acts as a series impedance which increases the output impedance of the overall circuit. That is, there is a natural voltage division between the reactance of inductor (180) and load impedance (136), which requires an increased input voltage in compensation, if the output voltage is to remain constant over changes in the resistance of load (186). This voltage division causes the output voltage to be a strong function of the resistance of load (186), which is another way of saying that the output impedance of the circuit is not small compared to the load resistance (186).

The diodes (183) shown in Figure 1-8 would ideally conduct whenever the voltage on their anodes was positive with respect to their cathodes, and would not conduct when the voltage was in the opposite polarity. This is what is called zero voltage switching, or ZVS, because the switching point, or transition, from the conducting to the nonconducting state occurs at zero voltage point in the waveform. Operating an FET device at ZVS is an advantage, because the losses are lowered, since the device does not have to discharge energy from its output capacitance, or the energy stored in capacitors (182), which are in parallel with the switches. As the output current through load (186) increases, the timing for the switches to produce ZVS must change, and may complicate the FET drive circuitry. In the description of the figures which follow, we shall nevertheless assume that the switches are operated at ZVS conditions, or that a true diode is used.

Figure 1-9 shows how the output voltage varies with changes in the value of capacitance (182) placed across diodes (183). These curves were plotted for an operating frequency of 3.39 MHz. As may be seen in Figure 1-9, as the value of capacitances (182) are increased, the output voltage (that is, the voltage across load resistance) (186) first begins to increase, but as the value of the capacitance (182) is increased still further, the voltage across load resistance (186) begins to drop again. Thus there is an optimum value for the capacitances (182) which obtains the highest voltage transfer function. In Figure 1-9 two curves are shown, curve (187) a value of inductance (180) of 40 nH, and curve (188) for a value of inductance (180) of 20 nH. Curve (187) shows that a peak in output voltage occurs

at a value for capacitances (182) of about 27 nF, while curve (188) shows that a peak occurs at a value for capacitances (182) of about 86 nF. Note that these are not a factor of two apart (86/27>3) as would be the case if the values of capacitances (182) and inductor (180) satisfied the resonance condition since the two curves are for values of inductor (180) which are a factor of two apart. This means that the condition for maximum output is not the same as for resonance at the frequency of the input power from generator (177). The two capacitors (180) may be replaced by a single capacitor (181) in a parallel position across the secondary winding of transformer (179) and inductor (180), with the same result, although the current in the diodes (183) will not be the same in this case.

Figures 1-10 and 1-11 show the voltage across load resistance (186) as a function of the load resistance (186). The slope of these curves is a measure of the output impedance of the circuit (178). That is, if the slope is zero, the output impedance is zero, and the circuit exhibits "natural regulation" without feedback. Curve (189) in Figure 1-10 and curve (192) in Figure 1-11 show that, for a value for capacitances (182) equal to the value which results in a peak in voltage across load resistance (186), a slope of nearly zero is obtained, without feedback. That is, for a proper selection of the value of capacitances (182) in relation to inductance (180), the voltage across load resistor (186) becomes relatively independent of the actual value of the load resistor (186) - the output is "naturally regulated". It will be seen that the advantage of "natural regulation" - regulation without feedback - is that one does not need to wait for a feedback system to recognize a change in output voltage compared to a reference, and to change some parameter internal to the circuit. Under the described conditions, the output voltage is held constant and maintained so within a cycle or two of the operating frequency, which is short compared to stable feedback systems.

Thus a system has been described which produces a stable output voltage over a wide range of load resistances without feedback, even under conditions of rapid change in the load resistance. For systems which can tolerate the change in output shown in the figures, no feedback is required. For systems which require tighter control of the output voltage under conditions of changing load, feedback may be added, and it will be noted that the teachings of the present invention reduce the requirement for action on the part of the feedback system, permitting simpler, faster, and less costly feedback circuits to be used.

As mentioned earlier, the circuit can be embodied in a variety of manners to achieve

the overall goals of this invention. For example, referring to Figure 1-12 as but one other example of a circuit design, in general, the circuit can be understood. It may have any combination of a variety more generically stated elements. First, it may have a constant output element, such as the constant output voltage element (161). In this arrangement, the constant output element serves to maintain some output parameter as a constant regardless of a variation such as may occur from the variable load. As one skilled in the art would readily understand, the parameter maintained may be selected from a great variety of parameters, including but not limited to parameters such as:

- a substantially constant switch voltage output which is substantially constant over all levels at which said variable load exists practically,
- a substantially constant load voltage input which is substantially constant over all levels at which said variable load exists practically,
- a substantially constant switch voltage Fourier transform which is substantially constant over all levels at which said variable load exists practically,
- a substantially constant switch voltage output waveform which is substantially constant over all levels at which said variable load exists practically,
- a substantially constant switch voltage transition endpoint which is substantially constant over all levels at which said variable load exists practically, and
- all permutations and combinations of each of the above

In the configuration shown, this constant output voltage element (161) has inductor L1 and capacitor C5 which may be tuned for series resonance at the fundamental frequency of operation, inductor L2 and capacitor C6 which may be tuned for parallel resonance at the fundamental frequency of operation, and capacitors C7 & C8 arranged to form a half supply with low AC impedance as is common for a half bridge configuration, with R5 representing the load to be powered. Of course, from these general principles, as a person of ordinary skill in the art would readily understand, other designs can be configured to achieve this basic goal.

Second, the system can include a constant trajectory element such as the constant trajectory element (162). In this arrangement, the constant trajectory element serves to maintain the response waveform (or even the Fourier component of the waveform) as substantially a constant regardless of a variation such as may occur from the variable load. In the configuration shown, this constant trajectory element (162) has inductor L4 connected

to a half supply (shown as capacitors C7 & C8). It provides a constant current at the time of transition from switch T1 conducting or switch T2 conducting (or visa versa) where diode D2 and capacitor C2 are adjunct elements of switch T1, and diode D3 and capacitor C4 are adjunct elements of switch T2. The trajectory which is maintained may even be held to one which present a continuous second derivative of voltage with respect to time. As shown herein, designs may also be configured to achieve a constant end point. The end point may or may not be zero, for instance, it may be desirable in certain designs to have a non-zero end point. That type of a design may include values such as: zero volts, a voltage which is less than a diode turn-on level, less than about 5% of said switch DC supply voltage, less than about 10% of said switch DC supply voltage, less than about 20% of said switch DC supply voltage, and less than about 50% of said switch DC supply voltage, each over all levels at which said variable load exists practically. Regardless, a constant result (trajectory, end point, or otherwise) can be important since it is the voltage at the moment of switch turn-on or the avoidance of turning on the body diode which can be highly important. Again, from all these general principles, as a person of ordinary skill in the art would readily understand, other designs can be configured to achieve each of these basic goals. Designs may thus provide a network which is substantially load independent and which provides a substantially trajectory fixed response. Further, any nonlinear transfer characteristics of any component, such as the varactor capacitance nature of many switches, the nonlinear transfer characteristics of a transformer, or the like, can be affirmatively utilized by the network as well for an optimal result.

Third, the circuit may include an energy maintenance element, such as the energy maintenance circuit (163). In this feature, the energy maintenance circuit (163) serves to maintain the energy needed as a constant regardless of a variation such as may occur from the variable load. In the configuration shown, this energy maintenance circuit (163) has a capacitor C6 configured in parallel with inductor L2, both being in parallel with the load shown as R5. This element may serve to supply substantially all of the rapid energy demand of the load such as discussed earlier. Again, as before other designs can be configured to achieve this basic goal.

Fourth, the circuit may have some type of stabilizer element such as the stabilizer element (164) shown. This stabilizer element (164)serves to absorb energy not in the

fundamental frequency in accordance with the principles discussed in US Patent No. 5,747,935, hereby incorporated by reference, to the assignee of the present invention.

Finally, the circuit may include an automatic bias network such as the direct bias alteration element (165) as shown for each switch. In this arrangement, these networks may include some type of voltage divider (166) with a conduction control element such as diode (167). Here, the voltage divider (166) uses two resistors R1 & R2 which may be selected to be equal, each with high values such as 1k ohm. This element provides a negative bias in proportion to the AC drive amplitude. The result can be a conduction period which is independent of the drive amplitude. It can thus provide a constant dead time (response time) when neither switch is in the conductive state. Again, from these general principles, as a person of ordinary skill in the art would readily understand, other designs can be configured to achieve this basic goal as well.

As illustrated in Figures 1-13 and 1-14, it can be seen how a properly configured system according to the present invention has the constancy features mentioned. The plots 1-4 show waveforms as follows:

1- the voltage at the junction between switches T1 and T2;

2- the output voltage across the load, R5;

3- the current through L1; and

4- the current through L4.

By comparing the high load and low load situations for the same network as shown between the two figures, several events can be noticed. These include the constant output voltage (A), constant end point (B and B'), constant trajectory (C and C'), constant response time period (D and D'), zero voltage switching (B and B'), and constantly an event of zero load current in the transition (E), all even though there is a highly varying power and load current as indicated by the current into the network at L1 (F and F'). Other features are also noticeable, as one skilled in the art should easily understand.

As mentioned earlier, buck converter topologies (such as shown in Figure 3-1) are in current use for powering microprocessors, especially for voltage regulation modules. For a 2.5 volt, 13 ampere requirement, a switching frequency of 300 kHz is becoming inadequate. To meet substantial step load changes an output capacitance (301) of 3 mF (millifarads) is becoming required. As microprocessor voltage requirements move downward toward 1.0 volt

at 50 amperes, the prior art topologies become even less suitable. With a drop in voltage (and an attendant drop in differential voltage tolerance) of 2.5 times, and an increase of current of 4 times, an output capacitor of 30 mF would be needed to maintain the required step response. It becomes increasingly difficult or impossible, however, to locate such a large capacitor close to the microprocessor connections. In addition, the cost of this approach increases with decreasing voltage. The other possibility would be to increase the frequency. The voltage waveform (302) shown in Figure 3-2 is typical for a buck converter. When the frequency increases in such an arrangement, however, the non-resonant edges of this waveform cause problems such as the commutation of FET output capacitance and prevent increasing the switching frequency above about a megahertz. This situation is rapidly becoming serious as microprocessors and other low voltage electronics are being developed which are increasingly difficult to provide suitable power for. The present invention permits the achievement of higher frequencies and currents as will be required. It permits frequencies such as greater than at least about 300 kHz, greater than at least about 500 kHz, greater than at least about 1 MHZ, greater than at least about 3 MHZ, greater than at least about 10 MHZ, and even greater than at least about 30 MHZ and beyond, and can be configured to handle currents of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and even more than about 100 amperes and beyond.

In one embodiment, an aspect of this invention is the basic change from a circuit converting DCto DCto a circuit transforming ACto DCmaking use of a transformer and a synchronous rectifier. A transformer is useful in this approach as it is possible to eliminate large currents being distributed to the converter input. The high current secondary can thus be located physically close to the load. One circuit for accomplishing this shown in Figure 3-3. With the invention disclosed, the energy conversion frequency can be increased substantially, thereby allowing the output capacitance (303) to remain small and be located adjacent to a given load such as the microprocessor interconnections. In fact, much higher conversion frequencies can be achieved and whereby the output capacitance can be substantially reduced. In the case of the 1.0 volt, 50 ampere requirement, the output capacitance (303) with the present invention can be 500 μF or lower, depending upon load requirements. In fact, with the present invention, designs can be accomplished which provide a network having an effective capacitance (that which causes an appreciable effect in the use

or circuit designed) which is less than about 10 millifarads, less than about 3 millifarads, less than about 1 millifarads, less than about 0.5 millifarads, and even less than about 0.3 millifarads.

Such a dramatic improvement can come through the incorporation of several elements individually or simultaneously. One primary goal of this invention is the elimination of frequency related limitations. Consequently it can be important to eliminate forced voltage commutation of any capacitors. The Synchronous Rectifier (SR) (304) device used may be a Field Effect Transistor (FET) with adjunct drain to source capacitance (305). This SR can always be commutated to the conducting state at a time when there is zero voltage across it.

Figure 3-3 shows a preferred embodiment for the rectification portion of a low voltage high current supply. The element LT (306) (total series inductance) is defined as the total of the transformer leakage inductance plus any other inductance in series with the transformer (inductance in the primary is simply scaled to the secondary). The element CT (total parallel capacitance) is defined as the total of the SR adjunct capacitance (305) (Coss), plus any external parallel capacitance of each SR (307) (Csr) plus any capacitance in parallel with the transformer secondary (308) (Cp).

There are several parameters which may be considered to optimize this circuit. If the load being powered has the possibility of high di/dt or if the load current can be a step function up or down then the following parameters could be considered:

- fundamental frequency of operation
- transformer turns ratio
- LT
- CT
- conduction angle (CA) for the SR's
- phase delay (PD) of the SR's

The output inductance LF and capacitance CF can be important but may have a less direct impact on the proper operation of the invention.

Also to be potentially considered is the basic relationship between conduction angle and efficiency. In prior art and practice the conduction angle for the SR's has been carefully chosen to be less than or equal to 180 degrees (i.e., no SR conduction overlap) to prevent a short circuit on the transformer secondary. This common misperception arises from lower

frequency assumptions. With the present invention, a conduction angle greater than 180 degrees is not only allowed but provides a fundamental benefit of operation. Conduction angles in the range of 300 degrees or higher are clearly demonstrated. With properly chosen LT, CT, phase angle (PA) and conduction angle (CA), the drain waveforms on the SR's (304) shown in Figure 3-4 can be realized. With these conditions, a low ratio of SR root-mean-square (RMS) current to output current can be realized. Ratios of <1.3:1 have been achieved.

Just as a general comparison, the waveforms from Figure 3-4 can be compared to Figure 3-2 from the prior art. They both share the low duty cycle aspect but it is clear in Figure 3-4 the switching of the SR occurs at zero volts and is ideally lossless.

Leakage Inductance & Overlapping Conduction Angle:

The transformer leakage inductance is a fundamental limiting factor for low voltage, high current, high frequency power supplies. It consists of an inductance in series with the transformer and has historically limited the conversion frequency.

In other art leakage inductance has been dealt with in various ways. Three patents, by Schlecht, Lee and Bowman, covering DCto DCconverters will be touched on as all include methods of handling the leakage inductance. In Schlecht et al., US Patent #4,788,634, the leakage inductance is managed by minimizing it. As that patent states: "It is desirable to limit the size of this leakage inductance to a negligibly small value compared to the resonant inductor (in this case the transformer primary inductance) such that the unilateral conducting element and controllable switch both have zero voltage switching transitions." In Lee et al., US Patent # 4,785,387 and Bowman US Patent # 4,605,999 the transformer leakage inductance is used in a circuit resonant at or slightly above the fundamental frequency. The goal for this circuit is to accomplish zero voltage switching both for the primary switches as well as for the rectifiers. However, the present invention shows use of the leakage inductance in a manner not resonant at the fundamental frequency.

One fundamental aspect of this invention is a circuit topology and class of operation which can make allowance for a larger leakage inductance. This benefit can be realized by the choice of a high conduction angle in the SR's. In fact, for some applications conduction angles even greater than 300 degrees are shown to be valuable. As the output voltage requirement is reduced and the current requirement is increased, both of these shifts result in

still higher conduction angles. The setting of this large conduction angle, the total inductance and total capacitance is done simultaneously with one of the desirable conditions being Zero Voltage Switching (ZVS) for the synchronous rectifiers. This allows operation at a higher frequency or, at a given frequency operation with a higher leakage inductance. This combination of high frequency operation and/or higher leakage inductance tolerance is a fundamental benefit of this design and may perhaps be a necessary benefit as microprocessor power requirements become more difficult to fulfill.

One additional note with respect to the total capacitance – the choice of location between putting the capacitor across the transformer (308) or across the SR's (307) changes the current waveform through the SR's but does not greatly affect the voltage waveform. With the capacitor across the transformer makes the current waveform more like a square wave while it is quasi-sinusoidal when the capacitor is across the SR. This difference can have significant ramifications as those of ordinary skill in the art should readily understand to some degree.

High Voltage on SR:

One general principal observed in rectifier circuit design is to minimize the reverse voltage stress across the rectifier device. Depending on the type of filter input the peak inverse voltage is usually in the range of being equal to the DC output voltage upwards to 1.4 times the output voltage or in rare circumstances up to twice the DC output voltage.

One consequence though of the high conduction angle is substantially higher voltage across the rectifier devices. For example in the circuit values disclosed here the output voltage is 1.8 volts while the voltage across the rectifier devices is 15 volts! Historically this type of circuit performance has been thought of as poor practice for a variety of reasons as those of ordinary skill in the art well understand. Perhaps this is one reason why such a valuable circuit has not been discovered to date.

But a high conductance angle with attendant high voltage across the SR during the non-conducting state has the benefit of low RMS current through the SR during the conducting state and is a condition for allowing large transformer leakage inductance. This circuit is ideally suited for low voltage, high current requirements. Furthermore it is well suited to loads which have a high di/dt requirement as a result of the higher operating

frequency and lower stored energy in the output capacitance. As it turns out the higher voltage requirement for the SR's is not troublesome. With current manufacturing technology there appears to little benefit to restraining the SR off state voltage to less than about 20 volts.

Gate Drive:

The next circuit being disclosed, Figure 3-5, is a gate drive circuit that derives its power from the ACinput and uses only passive elements. The gate drive of the SR's is also almost lossless. This all results in low cost and predictable performance. It is also important for higher frequency operation.

In addition it is possible to add a DCor low frequency bias to provide regulation or improve efficiency under various load conditions. In Figure 3-5 the point labeled BIAS INPUT is an example of an injection point for the control input. Varying the voltage on this input has the effect of varying the conduction angle of the SR's without effecting the DELAY ANGLE (Figure 3-4).

The correct phase angle for conduction of the SR's is determined by the gate drive. Referring to Figure 3-4, the angle labeled DELAY ANGLE could be derived by using something like elements L1, R1,2 and C1,2 of Figure 3-5. The inductance L1 includes the gate drive transformer leakage inductance.

There could be many variations of gate drive which embody these principles. This may be contrasted with conventional technology in which the gate drive is derived from a DC source and involves timing circuitry and switching devices.

Regulation with the SR:

It is possible to also control and/or regulate the output voltage by varying the SR Conduction Angle (CA). Consider Figure 3-3 again with the inclusion of the capacitor Cin 309 shown in dotted lines.

To select values for the controlled output circuit, first examine the case where the CA goes to 360 degrees for the SR's. This results in a zero DC output. The impedance of Cin 309 should now be matched to the value of LT (transformed to the primary by the square of the turns ratio) forming a parallel resonant circuit at the fundamental frequency. As can now be seen the AC input is only loaded by a parallel resonant circuit which in the ideal condition

is lossless.

There exists a continuum of CA's from 360 degrees downward until the full load condition is reached as before. With properly chosen circuit parameters ZVS switching can be maintained over the whole regulation range. One important requirement for ZVS is to provide constant phase relationship between conduction time and the ACinput. In the first order analysis, the only control input required is that shown in Figure 3-5.

Parametric Regulation:

Another method of providing regulation or control of the output could be to use parametric elements such as a varactor capacitor or saturable inductor to vary the output voltage. This can involve tuning the circuit to maximize the sensitivity to a given element and subsequently varying it. Another approach to this type of design is to begin with a basic transfer function having the characteristic of a voltage source. Then with small changes in one or more variable elements, the output can be held constant.

For some load requirements, this method of control may be the simplest or most cost effective. In particular loads which do not have high di/dt requirements or if the voltage required is not too low, parametric regulation may be ideal.

This method of control may have the disadvantage of poor response time for varying loads and poor input regulation. Another disadvantage is the incumbent increased sensitivity to component tolerances. In Figure 3-4 it can be seen that the CA is quite large. In general, the optimum CA increases for lower output voltages. One consequence when using parametric regulation is that it can become increasingly difficult to manage the increased sensitivity of the output voltage to the actual circuit values. If the component sensitivity becomes unmanageable, it may be preferable to optimize the rectification portion of the circuit for rectification only and regulate or control on the primary side of the transformer, where the impedance is higher. Layout and component values can be more manageable on the primary. Naturally linear components such as linearly variable capacitors, linearly variable inductors, or even linearly variable resistors (as should be understood, resistors are likely not the preferred component since they may cause losses) may be utilized as well.

Regulation on the Primary Side (with a single ended switch):

Figure 3-6 shows a simplified series switch on the primary side of the transformer. This circuit design can be used to vary the ACvoltage on the input of the transformer as a potential method of regulating the DCoutput. For instance, C1 (310) can be resonant with any residual inductive component of the rectifier circuit. C2 (311) may be low impedance at the fundamental frequency. The duty cycle of Q1 (312) can be controlled to vary the ACvoltage into the rectifier circuit. The phase delay (313) (L1, R1, and C4) may be chosen such that at the commencement of conduction the voltage across Q1 (312) is substantially zero. Further, the gate drive of Q1 can be set in similar fashion to the gate drive for the synchronous rectifier discussed earlier. The ACinput (315) may be used as the source power, transformed down in voltage and supplied to the gate through the delay circuit (313). In series with this drive signal can be a control input (314). By summing these two voltages the conduction angle can be varied from 0 to 360 degrees.

The conduction angle can be set by the control input and the phase relationship may be derived from the ACinput (315). With properly chosen circuit elements and delay time, Q1 (312) may be always commutated to the conducting state at a time when the voltage across it is zero. Thus the ACvoltage to the rectifier circuit can be varied from nearly zero to full while maintaining a lossless condition. Figure 3-7 shows a family of voltage waveforms across Q1 (312) (Vds for a FET switch) as a function of the control input. The waveform labeled 316 occurs with a low bias that results in a short conduction time. This condition provides minimum output. The waveform labeled (320) occurs with a high bias input and corresponds to a large conduction angle and provides maximum output. A simultaneous optimization of all parameters is also possible.

Regulation on the Primary Side (with a dual switch):

Figures 3-8 and 3-12 show other arrangements to provide regulation on the primary side of the transformer. This circuit can use two switches (323) that may operate 180 degrees out of phase. They can operate so as to move from a series resonance between a capacitor (321) and the leakage inductance (322) of the series transformer (320). This occurs when both switches are closed. This shorts the primary inductance and leaves only a series resonance already mentioned. This condition can give maximum ACvoltage to the rectifier circuit.

A second condition can occur when both switches are completely open. During this

condition the capacitors (324) (which includes the switch adjunct capacitance) can be in series across the series switch transformer. It is also possible to just use a capacitor across the transformer (325) or a combination of both. This total capacitance can be resonant with the magnetizing inductance of the transformer. This can create a parallel resonant circuit in series with the primary of the main transformer and may result in minimum ACvoltage to the rectifier circuit.

The third and normal condition can occur with a variable conduction angle. With the values disclosed this circuit can operate over the entire conduction range with ZVS.

Natural Regulation:

If certain values of total inductance, total capacitance and the output filter inductance are chosen correctly a new phenomenon can exist. The DCoutput voltage can remain relatively independent of the load current. This can occur without any variable elements or feedback.

Examples:

Choosing all the circuit parametric values can be a lengthy task. The following example is a general-purpose rectifier which may be optimized for powering a microprocessor operating at 1.8 volts and requiring 20 amperes. Using the circuit of Figure 3-3 the following parametric values may be appropriate:

Frequency	=	3.3 MHZ
Turns ratio	=	5:1
Input voltage	=	30 VAC
LT	=	30 nH
CT	=	10 nF
Cin	=	2 nF
L1 & L2	=	100 nH
Co	=	500μF
SR1& SR2	=	3 ea. FDS6880
Conduction angle	=	266 degrees
Delay angle	=	24 degrees

Figure 3-5 shows one embodiment of a SR gate drive; it consists of summation of

sinusoidal signal derived from the AC input plus a control signal. Also, the signal derived from the AC input can have an optimal delay for high efficiency. This circuit can produce a clean ACvoltage by taking advantage of the gate transformer leakage inductance and the gate capacitance to filter harmonics from the ACinput. This circuit can also show the creation of delay using R1,2, the combination of C1,2 (which includes the adjunct gate to source capacitance), and the inductor L1.

Output Trap:

Also shown in Figures 5 is a valuable filter element. C3 and L1 can form a parallel circuit resonant at twice the fundamental frequency. This parallel trap can provide the following advantages:

1) targeting largest ripple component only
2) storing very little energy - allowing fast loop control
3) sharply reducing the ACcurrent component of the connection to the output capacitor.

If this circuit powers a microprocessor, the C4 may be critically located to minimize inductance to the microprocessor. In this case the parallel trap can minimize the 'hot leads' problem for the connection from the rest of the circuit to the Cout.

Topology Variations:

Figures 3-9 A, B, C, and D show various topologies that may be used to implement the invention disclosed. The location of the total inductance and total capacitance is shown in each. Figure 3-9 A shows a single ended version. This can be an excellent topology for low cost concerns. Figure 3-9 B shows the effect of a transformer with a center tap. This circuit can be useful but may not utilize the transformer secondary fully. In addition for low voltages some realizations can require the secondary to have only one turn possibly making a center tap more difficult to implement. Figure 3-9 C shows inverting the SR's and the filter inductors. This circuit can be almost identical to the preferred one. In addition, the gate drive may not be referenced to a common source point making the drive circuit more complex (not shown). Figure 3-9 D shows a center tapped coil in place of a center tapped secondary. Some magnetic realizations make this circuit attractive. The essentials of this disclosure apply as

well.

The above examples represent only a few of the many designs possible. It should be obvious from these variations that other circuits may be designed which embody the ideas disclosed.

Third Harmonic Trap:

As may be understood from the above and the circuit designs, even or odd harmonics may exist or be of concern in different directions. For examples even order harmonics (i.e. 2nd, 4th, etc.) may be of concern in the forward direction and odd order harmonics (i.e. 3rd, 5th, etc.) may be of concern in the backward direction. Each may be addressed. Naturally, the highest order of such harmonics (ie. 2nd or 3rd) may be of initial interest. In the above discussion, a forward concerned, even order harmonic (e.g. the 2nd harmonic) was addressed. A backward concerned, odd order harmonic (e.g. the 3rd harmonic) may also be addressed. For the third harmonic, a series connection of an inductor and capacitor tuned to the third harmonic can be placed across the primary of the main VRM transformer. The preferred embodiment disclosed can draw an input current with substantial third harmonic content. By placing a trap on the input of the circuit the harmonic currents can flow through the trap and may not appear on the distribution supplying the circuit. As those skilled in the art would easily appreciate, by simple tuning, other harmonics can also be addressed.

More importantly, the efficiency of the rectifier can be improved with the addition of a third harmonic trap. The output circuit can be non-linear especially with the SR's having a long conduction angle (see Figure 3-4).

The DCoutput voltage from this circuit (Figures 3-4 & 3-10) can be equal to the integral of the voltage across the SR's (the average voltage across an inductor must be zero). Any distortion of this waveform can usually cause a reduction of the DCoutput voltage and consequently a reduction in efficiency. The third harmonic trap can preserve the natural peak of the SR voltage waveform.

Another potential benefit of the third harmonic trap is improved stability of a system where multiple SR circuits are fed from a common AC source. A local third harmonic trap can prevent SR circuits from interacting due to third harmonic current flowing along the distribution path.

Better put, without a third harmonic trap negative impedance can exist during a SR non-conduction time. Slight phase variations between SR circuits can result in high harmonic energy flowing between SR circuits. This can manifest itself in overall system instability. The presence of a third harmonic trap on the input of each SR circuit can locally satisfy the high order current requirement and can result in system stability.

Remote Power:

Devices like microprocessors can require low voltage, high current and exhibit high di/dt requirements. In the circuit of Figure 3-10, one problem which can exist is the di/dt limitation caused by the interconnect inductance (326). In this commonly used circuit, bypass capacitor (328) (which may be composed by many small capacitors in parallel) can be located near the microprocessor power pins. A larger capacitor, often called the bulk capacitor (327), can be located a small distance away. The short distance between capacitors (327) and (328) can form an inductor (326). This inductor (326) may limit the maximum di/dt the microprocessor can pull from the power supply. This can be especially true if the bypass capacitor is small (this is normally the case) and/or the basic power conversion frequency is too low (also the normal case). The bypass capacitor (328) may not be kept charged to the demanded voltage. Even if the power supply feeding capacitor (327) were ideal, or if capacitor (327)were replaced with an ideal voltage source a di/dt limit might still exist as a result of the interconnect inductance (326).

In the circuit of the invention this problem can be overcome. Referring to Figure 3-3, with this method and circuit the power conversion frequency can be increased to the point where the output capacitance can be small enough to be used as the microprocessor bypass capacitor which can be located adjacent to the microprocessor power pins; hence the output can be substantially non-capacitive. Thus the DCsupply voltage for the particular component can be located electrically remote to the component itself. This location can avoid the need for providing the VRM immediately adjacent to the particular component involved. Importantly, with the present invention, the DCvoltage can now be supplied at distances such as greater than about one-half an inch from the active portion (such as the microprocessor itself) of the component. By considering the active portion of the component, that is, the portion which consumes the power to achieve some desired function -- other than merely

transmitting the power such as wires or connectors or the like do, the true electrical effect of being remotely located can be fully appreciated. Significantly, with this design even greater distances for locating the power are possible. This may include distances of not only greater than about one-half an inch from the active portion, but also distances of greater than about one inch from the active portion and even distances of greater than about two inches from the active portion.

Quiet Power:

One of the problems facing the power supply industry as voltages drop, currents increase and di/dt requirements increase is noise. The circuit of Figure 3-1 is noisy for three reasons.

First the switching FET's (329) may be force commutated with steep voltage wavefronts. This can conduct and radiate noise into the surrounding structures. Compare the voltage waveforms of Figure 3-2 to those of Figure 3-4 to see the difference.

Second, the input circuit shown in Figure 3-1 can inject current into the ground path. As the FET's (329) are switched, large current can flow around loop (330)through the input capacitor (332), interconnect inductance (331) and FET's (329). The rate of change of current di/dt around this loop (330) can cause a voltage to be developed across inductor (331) which can be impressed onto the output voltage.

Third, the output of a circuit like Figure 3-1 can be inherently noisy as the DCoutput voltage is reduced. The DCoutput voltage is the average value of the voltage on point 2 shown in Figure 3-2. The voltage regulation method is sometimes dubbed pulse width modulation. For lower output voltages the pulse width becomes narrower to the point of difficulty of control. This is because a variation in width is a larger percentage of the total pulse width. This can create a shaky or noisy output voltage.

The circuits being disclosed can use zero voltage switching (ZVS) and can have smooth voltage waveforms in the rectification circuitry. Compare the voltage waveforms for Figure 3-2 (Prior Art) to Figure 3-4. It is obvious the waveforms on the invention will be less noisy. Secondly in one preferred embodiment the regulation can occur on the primary of the

transformer. This circuit is also ZVS plus it is isolated from the DCoutput voltage. These factors combined can make this approach much more suited to the next generation low voltage devices.

Additional Example:

Figures 3-11 and 3-12 show schematics for a complete ACto DCpower converter which can include the rectifier section, the gate drive, the series switch(es) along with a self derived DCpower supply and feedback from the output to the series switch for regulation. These schematics can embody much of what has been disclosed and can show a complete working 1.8 volt, 20 ampere DCpower supply suitable for loads requiring high di/dt. They can operate from an AC input buss at 30 volts RMS at a frequency of 3.39 MHZ. Finally, Figure 3-13 shows a potential design for some significant overall portions of the "silver box" as it may be configured in one preferred design.

Regulation on the Primary Side (with a variable capacitor):

The difference between a series switch on the primary side of the transformer and a capacitor is that the capacitor can present a lossless element. It may also be a linear element. Referring to the embodiment shown in Figure 3-14, the variable capacitor (C1) can create a phase shift between the primary AC energy source and the primary winding of the main transformer. In this configuration of the primary side regulator the mechanism of regulation is different from the one described previously for single and dual switches. No resonance of the magnetizing inductance is involved for the process of regulation. The primary elements of regulation for this topology may include the gate drive phase angle and the combination of series capacitor impedance with SR input impedance. Certain combinations of values of the series capacitor, the leakage inductance of the transformer(s), and the natural or additional capacitances of the SRs can provide a number of advantages including:

1) The circuit can be relatively insensitive to the magnetization inductance of the transformer (e.g. the stability of magnetic permeability of materials used for transformers can be largely irrelevant);

2) The phase delay circuit for the gate drive of the SR may no longer be required, (e.g. elements L1, R1, R2, C1 and C2 as shown in Figure 3-5 can be excluded);

3) In situations of a variable load, while undergoing the variable load conditions (e.g. an output current change) the SR gate drive voltage can adjust automatically to the most efficient value for the given load condition. For example, in one of the practical realizations of this circuit the efficiency at 10% current load was only 15% less than at full load!

4) The reactive part of the circuit can become constant under different load conditions and may be brought to zero (for series equivalent R-X circuit) by adding a parallel inductor to the input of the circuit. That is, the input impedance of the circuit can stay substantially non-reactive for the full range of load conditions. This is shown in Figure 3-15 for various load conditions. This aspect can be important for the primary energy source as most AC generators can work efficiently only into substantially resistive loads. This feature can allow the use of a less complicated AC generator for the primary power source.

5) the phenomenon of natural regulation can appear. This can result in limiting the range required for the series capacitor to achieve the full range of load regulation. For example, in one embodiment, the series capacitor value range needed is only ± 25% of the mean value. A simple varactor element may be used to achieve this.

Regulation on the Primary Side (with a switch equivalent of the variable capacitor):

As a result of the limited range of the capacitance required a ZVS switch can be used as an analog equivalent on the primary side of transformer. The configuration of one realization of the switch equivalent can be similar to that described above with regard to Fig. 3-8, but it operates in a different mode. This circuit can use two switches that may operate 180 degrees out of phase as can be understood from Figure 3-12. The circuit may be galvanically isolated from the SR with a transformer. There may be no special requirements for the transformer except in many cases it may need to have stable leakage inductance. The leakage inductance value can also be taken into account during circuit design and compensated if necessary. Neither magnetization inductance nor leakage inductance may need to be part of a resonant circuit. There also may be no special requirements for stability

of the core magnetic permeability for the transformer. With properly chosen circuit parameters ZVS switching and equivalence to the linear variable capacitor can also be maintained over the whole regulation range. Control of the value of effective capacitance may be set by the control DCbias voltage on the FET gates. In contrast to the Series Switch embodiment described above, the waveform across the insulation transformer may be substantially sinusoidal over the whole regulation range and the amplitude may only change under a different load condition.

Output Transformer:

Yet another potentially independent aspect of the invention is shown in Figure 3-14. This shows another option for the output filter element for the SR. Instead of two output inductors such as Lf shown in Fig. 3-3, only one transformer with 1:1 ratio can be used. More generally, the output transformer may simply be two output inductances (W3 and W4 in Fig. 3-14) which are coupled in some manner. By using a magnetic coupling or even a transformer, the following advantages can be realized:

1) Only one magnetic element instead of two may be used;
2) The fundamental frequency ACcurrent through the magnetic elements may be sharply reduced, reducing also the radiated ACmagnetic field;
3) Leakage inductance of the transformer may b used as a filtering element for the output of the SR. Again, leakage inductance in the first approach may not depend on magnetic permeability of the core hence no special requirements for magnetic material stability;
4) The output DCcurrent from the two halves of the SR may flow through the transformer in opposite directions and cancel each other so the resulting DCmagnetic field in the transformer core may be nearly zero. As a result there may be no magnetic saturation in the core and a small amount of magnetic material can be used in a closed configuration (toroid).

The discussion included in this patent is intended to serve as a basic description. The reader should be aware that the specific discussion may not explicitly describe all embodiments possible; many alternatives are implicit. It also may not fully explain the

generic nature of the invention and may not explicitly show how each feature or element can actually be representative of a broader function or of a great variety of alternative or equivalent elements. A variety of changes may be made without departing from the essence of the invention. All these are implicitly included in this disclosure. Where the invention is described in device-oriented terminology, each element of the device implicitly performs a function. Apparatus claims are included for many of the embodiments described, however only initial method claims are presented. Both additional method claims to track the apparatus claims presented and even additional method and/or apparatus to address the various functions the invention and each element performs may be included. Product by process claims or the like may also be added to any results achieved through such systems. Importantly, it should be understood that neither the description, nor the terminology, nor the specific claims presented is intended to limit the scope of the patent disclosure or the coverage ultimately available. Coverage for computer system as well as other electronics items may be presented and should be understood as encompassed by this application regardless of what is initially presented or the title indicated. All this should be particularly noted with respect to the method claims as well. Although claims directed to the apparatus have been included in various detail, for administrative efficiencies, only initial claims directed toward the methods have been included. Naturally, the disclosure and claiming of the apparatus focus in detail is to be understood as sufficient to support the full scope of both method and apparatus claims. Additional method claims may and likely will be added at a later date when appropriate to explicitly claim such details. Thus, the present disclosure is to be construed as encompassing the full scope of method claims, including but not limited to claims and subclaims similar to those presented in a apparatus context. In addition other claims for embodiments disclosed but not yet claimed may be added as well.

Further, the use of the principles described herein may result in a wide variety of configurations and, as mentioned, may permit a wide variety of design tradeoffs. In addition, each of the various elements of the invention and claims may also be achieved in a variety of manners or may be presented independently. This disclosure should be understood to encompass each such variation and the various combinations and permutations of any and all elements or applications. Particularly, it should be understood that as the disclosure relates to elements of the invention, the words for each element may be expressed by equivalent

apparatus terms or method terms -- even if only the function or result is the same. Such equivalent, broader, or even more generic terms should be considered to be encompassed in the description of each element or action. Such terms can be substituted where desired to make explicit the implicitly broad coverage to which this invention is entitled. As but one example, it should be understood that all action may be expressed as a means for taking that action or as an element which causes that action. Similarly, each physical element disclosed should be understood to encompass a disclosure of the action which that physical element facilitates. Regarding this last aspect, the disclosure of a "switch" should be understood to encompass disclosure of the act of "switching" -- whether explicitly discussed or not -- and, conversely, were there only disclosure of the act of "switching", such a disclosure should be understood to encompass disclosure of a "switch" or even a "means for switching." Such changes and alternative terms are to be understood to be explicitly included in the description as is particularly true for the present invention since its basic concepts and understandings are fundamental in nature and can be applied in a variety of ways to a variety of fields.

Furthermore, any references mentioned in the application for this patent as well as all references listed in any list of references filed with the application are hereby incorporated by reference, however, to the extent statements might be considered inconsistent with the patenting of this invention such statements are expressly not to be considered as made by the applicant.

Finally, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", should be understood to imply the inclusion of a stated element or step or group of elements or steps but not the exclusion of any other element or step or group of elements or steps. Additionally, the various combinations and permutations of all elements or applications can be created and presented. All can be done to optimize performance in a specific application.

VI. CLAIMS

What is claimed is:

1. A DCpowered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DCsignal;

c. an inverter element responsive to said DCsignal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising;

1) an alternative power input;

2) at least one voltage regulation module transformer which is responsive to said alternative power input;

3) a first switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

4) a second switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

5) a passive rectifier control to which said first and said second switched voltage regulation module rectifier elements are responsive;

6) a bias input to which said passive rectifier control is responsive;

7) a second harmonics trap which is responsive to said first and said second voltage regulation module rectifier elements; and

8) a substantially non-capacitive DCoutput system which is responsive to said second harmonics trap; and

h. at least one computer component responsive to said DCsupply output.

2. A DCpowered computer system as described in claim 1 wherein said computer component responsive to said remote power DCsupply system comprises a component operating at a nominal DCvoltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

3. A DCpowered computer system as described in claim 2 wherein said computer component is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

4. A DCpowered computer system as described in claim 3 wherein said computer component comprises a component operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

5. A DCpowered computer system as described in claim 1 wherein said passive rectifier control to which said first and said second switched voltage regulation module rectifier elements are responsive comprises an alternating control input.

6. A DCpowered computer system as described in claim 5 wherein said alternating control input comprises a sinusoidal drive system to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive.

7. A DCpowered computer system as described in claim 6 wherein said voltage regulation module further comprises:

a. a first rectifier inductive output responsive to said first switched voltage regulation module rectifier element;

b. a second rectifier inductive output responsive to said second switched voltage regulation module rectifier element; and

c. a rectifier junction responsive to both said first rectifier inductive output and said second rectifier inductive output, and

wherein said second harmonics trap comprises a parallel inductor and parallel capacitor connected to said rectifier junction.

8. A DCpowered computer system as described in claim 7 wherein said voltage regulation module further comprises an alternating input voltage regulator to which said voltage regulation module transformer is responsive.

9. A DCpowered computer system as described in claim 8 wherein said alternating input voltage regulator comprises a variable capacitor.

10. A DCpowered computer system as described in claim 8 wherein said alternating input voltage regulator comprises a series switch element.

11. A DCpowered computer system as described in claim 10 wherein said series switch element comprises two switch elements.

12. A DCpowered computer system as described in claim 8 wherein said alternating input voltage regulator comprises a regulator isolation element.

13. A DCpowered computer system as described in claim 11 wherein said two switch elements comprise switch elements driven at about a 180 degree phase relationship.

14. A DCpowered computer system as described in claim 8 wherein said voltage

regulation module further comprises a DCoutput coupling responsive to both said first rectifier inductive output and said second rectifier inductive output.

15. A DCpowered computer system as described in claim 14 wherein said voltage regulation module further comprises a third harmonics trap.

16. A DCpowered computer system as described in claim 15 wherein said voltage regulation module transformer has a primary side and wherein said third harmonics trap comprises a third harmonics trap electrically tied to said primary side of said voltage regulation module transformer element.

17. A DCpowered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DCsignal;

c. an inverter element responsive to said DCsignal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising;

1) a first voltage regulation module rectifier element;

2) a second voltage regulation module rectifier element;

3) an overlapping rectifier control system to which said first and

said second voltage regulation module rectifier elements are responsive; and

4) a DCsupply output responsive to said first voltage regulation module rectifier element and said second voltage regulation module rectifier element; and

h. at least one computer component responsive to said DCsupply output.

18. A DCpowered computer system as described in claim 17 wherein said overlapping rectifier control system to which said first and said second voltage regulation module rectifier elements are responsive causes conduction in both said first voltage regulation module rectifier element and said second voltage regulation module rectifier element to simultaneously occur at at least some time.

19. A DCpowered computer system as described in claim 17 wherein said overlapping rectifier control system to which said first and said second voltage regulation module rectifier elements are responsive comprises an overlapping rectifier control system configured to create a conduction angle in each of said first and said second voltage regulation module rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DCoutput current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DCoutput current, a conduction angle which creates a rectifier RMS current which less than about 1.5 as compared to a DCoutput current, and a conduction angle which creates zero voltage on said rectifier at the time when said rectifier is switched to a conductive state.

20. A DCpowered computer system as described in claim 17 or 18 wherein said voltage regulation module further comprises high voltage response circuitry which subjects said first and said second voltage regulation module rectifier elements to a high voltage when said first and said second voltage regulation module rectifier elements

are in a non-conducting state.

21. A DCpowered computer system as described in claim 20 wherein said high voltage response circuitry subjects said first and said second voltage regulation module rectifier elements to a voltage selected from a group consisting of at least about 1.4 times the voltage to which said first and said second voltage regulation module rectifier elements are subjected in a conducting state, at least about 8 times the voltage to which said first and said second voltage regulation module rectifier elements are subjected in a conducting state, at least about 15 volts, and at least about 20 volts when said first and said second voltage regulation module rectifier elements are in a non-conducting state.

22. A DCpowered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DCsignal;

c. an inverter element responsive to said DCsignal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one voltage regulation module responsive to said power distribution system comprising;

1) at least one voltage regulation module rectifier element;

2) at least one harmonic trap which is responsive to said voltage regulation module rectifier element;

3) a DCsupply output responsive to said voltage regulation module rectifier element; and

h. at least one computer component responsive to said DCsupply output.

23. A DCpowered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element substantially eliminates transmission away from said voltage regulation module of at least one harmonic frequency.

24. A DCpowered computer system as described in claim 22 wherein said voltage regulation module rectifier element comprises a switched voltage regulation module rectifier element.

25. A DCpowered computer system as described in claim 24 wherein said switched voltage regulation module rectifier element comprises:

a. a first switched voltage regulation module rectifier element; and

b. a second switched voltage regulation module rectifier element.

26. A DCpowered computer system as described in claim 22 or 25 wherein said voltage regulation module further comprises a voltage regulation module transformer element to which said voltage regulation module rectifier element is responsive.

27. A DCpowered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises a forward transmitted harmonics trap.

28. A DCpowered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises an even harmonics trap.

29. A DCpowered computer system as described in claim 28 wherein said even harmonics

trap comprises a second harmonics trap.

30. A DCpowered computer system as described in claim 29 wherein said voltage regulation module comprises:

a. a first switched voltage regulation module rectifier element;

b. a first rectifier inductive output responsive to said first switched voltage regulation module rectifier element;

c. a second switched voltage regulation module rectifier element;

d. a second rectifier inductive output responsive to said second switched voltage regulation module rectifier element; and

e. a rectifier junction responsive to both said first rectifier inductive output and said second rectifier inductive output, and

wherein said second harmonics trap comprises a parallel inductor and parallel capacitor connected to said rectifier junction and tuned to said second harmonic frequency.

31. A DCpowered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises a backward transmitted harmonics trap.

32. A DCpowered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises an odd harmonics trap.

33. A DCpowered computer system as described in claim 32 wherein said odd harmonics trap comprises a third harmonics trap.

34. A DCpowered computer system as described in claim 33 wherein said voltage regulation module further comprises a voltage regulation module transformer element to which said voltage regulation module rectifier element is responsive and having a primary side and wherein said third harmonics trap comprises a third harmonics trap

tied to said primary side of said voltage regulation module transformer element.

35. A DCpowered computer system as described in claim 34 wherein said third harmonics trap tied to said primary side of said voltage regulation module transformer element comprises a series inductor and a series capacitor tied to said primary side of said voltage regulation module transformer element.

36. A DCpowered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DCsignal;

c. an inverter element responsive to said DCsignal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising:

1) at least one switched voltage regulation module rectifier element;

2) at least one passive rectifier control to which said switched voltage regulation module rectifier element is responsive; and

3) a DC supply output responsive to said switched voltage regulation module rectifier element; and

h. at least one computer component responsive to said DC supply output.

37. A DC powered computer system as described in claim 36 wherein said switched voltage regulation module rectifier element comprises:

a. a first switched voltage regulation module rectifier element; and

b. a second switched voltage regulation module rectifier element.

38. A DC powered computer system as described in claim 37 wherein said voltage regulation module further comprises a voltage regulation module transformer element to which said voltage regulation module rectifier element is responsive.

39. A DC powered computer system as described in claim 36 wherein said passive rectifier control to which said switched voltage regulation module rectifier element is responsive comprises an alternating control input.

40. A DC powered computer system as described in claim 38 wherein said voltage regulation module transformer element to which said voltage regulation module rectifier element is responsive has an alternating transformer input and wherein said alternating control input is responsive to said alternating transformer input.

41. A DC powered computer system as described in claim 36 or 39 wherein said passive rectifier control comprises a bias input.

42. A DC powered computer system as described in claim 41 wherein said passive rectifier control to which said switched voltage regulation module rectifier element is responsive comprises a rectifier control transformer having a secondary side and wherein said bias input is electrically connected to said secondary side of said rectifier control transformer.

43. A DC powered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising;

   1) a first switched voltage regulation module rectifier element;

   2) a first rectifier output inductance responsive to said first switched voltage regulation module rectifier element;

   3) a second switched voltage regulation module rectifier element;

   4) a second rectifier output inductance responsive to said second switched voltage regulation module rectifier element; and

   5) a DC output coupling responsive to both said first rectifier output inductance and said second rectifier output inductance;

   6) a DC supply output responsive to said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element; and

h. at least one computer component responsive to said DC supply output.

44. A DC powered computer system as described in claim 43 wherein said DC output coupling responsive to both said first rectifier output inductance and said second rectifier output inductance comprises a magnetic coupling.

45. A DC powered computer system as described in claim 43 wherein said first rectifier output inductance, said second rectifier output inductance, and said DC output coupling responsive to both said first rectifier output inductance and said second rectifier output inductance comprise a voltage regulation module output transformer.

46. A DC powered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system;

h. a remote power DC supply system responsive to said electrically remote voltage regulation module and which provides computer components power at locations electrically remote from said voltage regulation module; and

i. at least one electrically remote low voltage, high current computer component responsive to said remote power DC supply system.

47. A DC powered computer system as described in claim 46 wherein said low voltage, high current computer component has an active component and wherein said remote

power DC supply system provides said low voltage, high current computer components power over a distance selected from a group consisting of over at least about one-half inch from said voltage regulation module to said active portion of said low voltage, high current computer component, and over at least about one inch from said voltage regulation module to said active portion of said low voltage, high current computer component, over at least about two inches from said voltage regulation module to said active portion of said low voltage, high current computer component.

48. A DC powered computer system as described in claim 46 wherein said low voltage, high current computer component responsive to said remote power DC supply system comprises a component operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

49. A DC powered computer system as described in claim 46 or 48 wherein said low voltage, high current computer component is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

50. A DC powered computer system as described in claim 46 or 48 wherein said low voltage, high current computer component comprises a component operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

51. A DC powered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power

to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least one electrically remote voltage regulation module responsive to said power distribution system comprising:

   1) an alternative power input;

   2) at least one voltage regulation module transformer element which is responsive to said alternative power input;

   3) at least one voltage regulation module rectifier element which is responsive to said voltage regulation module transformer element; and

   4) a substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element; and

h. at least one computer component responsive to said substantially non-capacitive DC output system.

52. A DC powered computer system as described in claim 51 wherein said at least one computer component responsive to said substantially non-capacitive DC output system comprises a low voltage, high current computer component.

53. A DC powered computer system as described in claim 51 wherein said substantially non-capacitive DC output system comprises a DC output system having an effective

capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

54. A voltage regulation module comprising:

a. an alternative power input;

b. at least one voltage regulation module transformer which is responsive to said alternative power input;

c. a first switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

d. a second switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

e. a passive rectifier control to which said first and said second switched voltage regulation module rectifier elements are responsive;

f. a bias input to which said passive rectifier control is responsive;

g. a second harmonics trap which is responsive to said first and said second voltage regulation module rectifier elements; and

h. a substantially non-capacitive DC output system which is responsive to said second harmonics trap.

55. A DC powered computer system as described in claim 17 wherein said first voltage regulation module rectifier element comprises a first switched voltage regulation module rectifier element and wherein said second voltage regulation module rectifier element comprises a second switched voltage regulation module rectifier element.

56. A DC powered computer system as described in claim 17 wherein said first voltage regulation module rectifier element comprises a first controllable diode element and wherein said second voltage regulation module rectifier element comprises a second

controllable diode element.

57. A DC powered computer system as described in claim 17 wherein said voltage regulation module further comprises a voltage regulation module transformer element to which said first and said second voltage regulation module rectifier elements are responsive.

58. A DC voltage regulation module comprising:

a. a first voltage regulation module rectifier element;

b. a second voltage regulation module rectifier element;

c. an overlapping rectifier control system to which said first and said second voltage regulation module rectifier elements are responsive; and

d. a DC supply output responsive to said first voltage regulation module rectifier element and said second voltage regulation module rectifier element.

59. A DC voltage regulation module as described in claim 58 wherein said overlapping rectifier control system to which said first and said second voltage regulation module rectifier elements are responsive causes conduction in both said first voltage regulation module rectifier element and said second voltage regulation module rectifier element to simultaneously occur at at least some time.

60. A DC voltage regulation module as described in claim 58 wherein said first voltage regulation module rectifier element comprises a first switched voltage regulation module rectifier element and wherein said second voltage regulation module rectifier element comprises a second switched voltage regulation module rectifier element.

61. A DC voltage regulation module as described in claim 58 wherein said first voltage regulation module rectifier element comprises a first controllable diode element and wherein said second voltage regulation module rectifier element comprises a second

controllable diode element.

62. A DC voltage regulation module as described in claim 58 wherein said overlapping rectifier control system to which said first and said second voltage regulation module rectifier elements are responsive comprises an overlapping rectifier control system configured to create a conduction angle in each of said first and said second voltage regulation module rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on said rectifier at the time when said rectifier is switched to a conductive state.

63. A DC voltage regulation module as described in claim 58 or 62 wherein said voltage regulation module further comprises high voltage response circuitry which subjects said first and said second voltage regulation module rectifier elements to a high voltage when said first and said second voltage regulation module rectifier elements are in a non-conducting state.

64. A DC voltage regulation module as described in claim 63 wherein said high voltage response circuitry subjects said first and said second voltage regulation module rectifier elements to a voltage selected from a group consisting of at least about 1.4 times the voltage to which said first and said second voltage regulation module rectifier elements are subjected in a conducting state, at least about 8 times the voltage to which said first and said second voltage regulation module rectifier elements are subjected in a conducting state, at least about 15 volts, and at least about 20 volts when said first and said second voltage regulation module rectifier elements are in a

non-conducting state.

65. A DC voltage regulation module as described in claim 58 wherein said voltage regulation module further comprises a voltage regulation module transformer element to which said first and said second voltage regulation module rectifier elements are responsive.

66. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;
b. rectifying said AC utility power to a DC signal;
c. inverting said DC signal to establish an alternating power output;
d. distributing power to an electrically remote location;
e. switching a first switched rectifier element to create a conduction state;
f. switching a second switched rectifier element to create a conduction state while said first switched rectifier element is in a conduction state;
g. creating a component DC supply voltage as a result of said steps of switching said first and said second switched rectifier elements; and
h. powering said computer component from said component DC supply voltage.

67. A DC powered computer system as described in claim 33 wherein said voltage regulation module comprises:

a. a first voltage regulation module rectifier element;
b. a second voltage regulation module rectifier element; and
c. an overlapping rectifier control system to which said first and said second voltage regulation module rectifier elements are responsive.

68. A DC powered computer system as described in claim 33 wherein said voltage regulation module comprises:

a. a first voltage regulation module rectifier element;
b. a second voltage regulation module rectifier element; and

c. a common alternating voltage source to which both said first and said second voltage regulation module rectifier elements are responsive.

69. A DC powered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises:

a. a forward transmitted harmonics trap; and

b. a backward transmitted harmonics trap.

70. A DC powered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises:

a. an even harmonics trap; and

b. an odd harmonics trap.

71. A DC powered computer system as described in claim 22 wherein said harmonic trap which is responsive to said voltage regulation module rectifier element comprises:

a. a second harmonics trap; and

b. a third harmonics trap.

72. A DC powered computer system as described in claim 22 wherein said voltage regulation module comprises:

a. a voltage regulation module transformer element which has a primary side;

b. a first switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

c. a first rectifier inductive output responsive to said first switched voltage regulation module rectifier element;

d. a second switched voltage regulation module rectifier element responsive to said voltage regulation module transformer element;

e. a second rectifier inductive output responsive to said second switched voltage regulation module rectifier element;

f. a rectifier junction responsive to both said first rectifier inductive

output and said second rectifier inductive output;

g. a parallel inductor electrically connected to said rectifier junction;

h. a parallel capacitor electrically connected to said rectifier junction in parallel with said parallel inductor;

i. a series inductor electrically connected to said primary side of said voltage regulation module transformer element; and

j. a series capacitor electrically connected to said primary side of said voltage regulation module transformer element in series with said series inductor.

73. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. remotely rectifying said power with a rectifier frequency to establish a component DC supply voltage;

f. trapping a harmonic of said rectifier frequency; and

g. powering said computer component from said component DC supply voltage.

74. A DC powered computer system as described in claim 41 wherein said bias input comprises a DC input.

75. A DC powered computer system as described in claim 41 wherein said bias input comprises a low frequency input.

76. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. passively driving at least one switch to rectify said power and establish a component DC supply voltage; and

f. powering said computer component from said component DC supply voltage.

77. A DC powered computer system as described in claim 45 wherein said voltage regulation module output transformer comprises a one-to-one transformer.

78. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. switching a first switched rectifier element to create a first switched rectifier output from said distributed power;

f. transmitting said first switched rectifier output through a first rectifier output inductance;

g. switching a second switched rectifier element to create a second switched rectifier output from said distributed power;

h. transmitting said second switched rectifier output through a second rectifier output inductance;

i coupling said first and second rectifier output inductances and thereby creating a component DC supply voltage; and

j. powering said computer component from said component DC supply voltage.

79. A DC powered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power

to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least voltage regulation module responsive to said power distribution system comprising:

   1) a first switched voltage regulation module rectifier element;

   2) a second switched voltage regulation module rectifier element;

   3) a sinusoidal drive system to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive; and

   4) a DC supply output responsive to said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element; and

h. at least one computer component responsive to said DC supply output.

80. A DC powered computer system as described in claim 79 wherein said voltage regulation module further comprises a voltage regulation module transformer element to which both said first and said second switched voltage regulation module rectifier elements are responsive.

81. A DC powered computer system as described in claim 80 wherein said voltage regulation module transformer element to which said voltage regulation module rectifier element is responsive has an alternating transformer input and wherein said

sinusoidal drive system is responsive to said alternating transformer input.

82. A DC powered computer system as described in claim 79 wherein said DC supply output comprises a substantially non-capacitive DC output system.

83. A DC powered computer system as described in claim 82 wherein said substantially non-capacitive DC output system comprises a DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

84. A DC powered computer system as described in claim 79 wherein said sinusoidal drive system to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive comprises a drive isolation element.

85. A DC powered computer system as described in claim 84 wherein said drive isolation element comprises a drive system transformer.

86. A DC powered computer system as described in claim 79 or 84 wherein said power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element comprises a substantially sinusoidal alternating signal power distribution system.

87. A DC powered computer system as described in claim 79 wherein said sinusoidal drive system to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive

comprises a high frequency sinusoidal drive system.

88. A DC powered computer system as described in claim 87 wherein said high frequency sinusoidal drive system comprises a drive system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second switched voltage regulation module rectifiers, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of said sinusoidal drive system, and any permutations or combinations of the above.

89. A DC powered computer system as described in claim 80 wherein said voltage regulation module responsive to said power distribution system further comprises an alternating input voltage regulator and wherein said voltage regulation module transformer is responsive to said alternating input voltage regulator.

90. A DC powered computer system as described in claim 89 wherein said alternating input voltage regulator comprises an alternating input sinusoidal drive system.

91. A DC powered computer system as described in claim 79 wherein said sinusoidal drive system comprises a zero voltage switching control element to which said to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive.

92. A DC powered computer system as described in claim 79 or 81 wherein said sinusoidal drive system to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive comprises a bias input.

93. A DC powered computer system as described in claim 92 wherein said bias input comprises a DC input.

94. A DC powered computer system as described in claim 92 wherein said bias input comprises a low frequency input.

95. A DC powered computer system as described in claim 92 wherein said sinusoidal drive system to which said first switched voltage regulation module rectifier element and said second switched voltage regulation module rectifier element are responsive comprises a rectifier control transformer having a secondary side and wherein said bias input is electrically connected to said secondary side of said rectifier control transformer.

96. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;
b. rectifying said AC utility power to a DC signal;
c. inverting said DC signal to establish an alternating power output;
d. distributing power to an electrically remote location;
e. switching a first switched rectifier element responsive to said distributed power;
f. switching a second switched rectifier element responsive to said distributed power;
g. sinusoidally driving said first and said second switched rectifier elements to establish a component DC supply voltage; and
h. powering said computer component from said component DC supply voltage.

97. A DC powered computer system as described in claim 46 wherein said electrically remote voltage regulation module comprises a substantially non-capacitive DC output system.

98. A DC powered computer system as described in claim 97 wherein said substantially non-capacitive DC output system comprises a DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

99. A DC powered computer system as described in claim 46 wherein said voltage regulation module responsive to said power distribution system comprises a voltage regulation module isolation element.

100. A DC powered computer system as described in claim 99 wherein said voltage regulation module isolation element comprises a voltage regulation module transformer.

101. A DC powered computer system as described in claim 100 wherein said voltage regulation module isolation element further comprises a voltage regulation module rectifier drive transformer.

102. A DC powered computer system as described in claim 46, 48, or 97 wherein said power distribution system which provides computer components power at locations electrically remote from said inverter element comprises a substantially sinusoidal alternating signal power distribution system.

103. A DC powered computer system as described in claim 102 wherein said substantially sinusoidal alternating signal power distribution system comprises a distribution system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about

3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second switched voltage regulation module rectifiers, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of said sinusoidal drive system, and any permutations or combinations of the above.

104. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. establishing a component DC supply voltage;

f. transmitting said component DC supply voltage to an electrically remote computer component; and

g. powering said computer component from said component DC supply voltage.

105. A voltage regulation module comprising:

a. an alternative power input;

b. at least one voltage regulation module transformer which is responsive to said alternative power input;

c. at least one voltage regulation module rectifier element which is responsive to said voltage regulation module transformer element; and

d. a substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element.

106. A DC powered computer system as described in claim 105 wherein said substantially non-capacitive DC output system comprises a DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less

than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

107. A DC powered computer system as described in claim 105 wherein said voltage regulation module rectifier element which is responsive to said voltage regulation module transformer element comprises:

a. a first switched voltage regulation module rectifier element; and

b. a second switched voltage regulation module rectifier element.

108. A DC powered computer system as described in claim 105 wherein said voltage regulation module comprises a high frequency drive system to which said voltage regulation module rectifier element is responsive.

109. A DC powered computer system as described in claim 108 wherein said high frequency drive system comprises a drive system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second switched voltage regulation module rectifiers, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of said sinusoidal drive system, and any permutations or combinations of the above.

110. A DC powered computer system as described in claim 105 wherein said substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element comprises a DC output system operating at a nominal DC

voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

111. A DC powered computer system as described in claim 105 wherein said substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element comprises a DC output system capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

112. A DC powered computer system as described in claim 105 wherein said substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element comprises a DC output system operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

113. A DC powered computer system as described in claim 51 wherein said voltage regulation module rectifier element which is responsive to said voltage regulation module transformer element comprises:

a. a first switched voltage regulation module rectifier element; and

b. a second switched voltage regulation module rectifier element.

114. A DC powered computer system as described in claim 51 wherein said voltage regulation module comprises a high frequency drive system to which said voltage regulation module rectifier element is responsive.

115. A DC powered computer system as described in claim 114 wherein said high frequency drive system comprises a drive system operating at a frequency selected

from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second switched voltage regulation module rectifiers, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of said sinusoidal drive system, and any permutations or combinations of the above.

116. A DC powered computer system as described in claim 51 wherein said substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element comprises a DC output system operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

117. A DC powered computer system as described in claim 51 wherein said substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element comprises a DC output system capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

118. A DC powered computer system as described in claim 51 wherein said substantially non-capacitive DC output system which is responsive to said voltage regulation module rectifier element comprises a DC output system operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

119. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. providing an alternating input at said electrically remote location;

f. transforming said alternating input at said electrically remote location to create a transformed alternating output;

g. rectifying said transformed alternating output at said electrically remote location to create a component DC supply voltage;

h. transmitting said component DC supply voltage through a substantially non-capacitive DC output system; and

i. powering said computer component from said component DC supply voltage.

120. A DC powered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least voltage regulation module responsive to said power

distribution system comprising:

1) an alternating input voltage regulator;

2) a voltage regulation module transformer responsive to said alternating input voltage regulator;

3) at least one voltage regulation module rectifier element responsive to said voltage regulation module transformer;

4) a DC supply output responsive to said voltage regulation module rectifier element; and

h. at least one computer component responsive to said DC supply output.

121. A DC powered computer system as described in claim 120 wherein said voltage regulation module transformer element has a primary side and wherein said primary side of said voltage regulation module transformer element is responsive to said alternating input voltage regulator.

122. A DC powered computer system as described in claim 121 wherein said alternating input voltage regulator comprises a variable capacitor.

123. A DC powered computer system as described in claim 121 wherein said alternating input voltage regulator comprises a series switch element.

124. A DC powered computer system as described in claim 123 wherein said series switch element comprises two switch elements.

125. A DC powered computer system as described in claim 121 wherein said alternating input voltage regulator comprises a regulator isolation element.

126. A DC powered computer system as described in claim 121 wherein said two switch elements comprise switch elements driven at about a 180 degree phase relationship.

127. A DC powered computer system as described in claim 120 wherein said alternating

input voltage regulator comprises a linear regulation element.

128. A DC powered computer system as described in claim 127 wherein said linear regulation element comprises an element selected from a group consisting of a variable linear capacitor, and a variable linear inductor.

129. A DC powered computer system as described in claim 120 wherein said alternating input voltage regulator comprises a parametric regulation element.

130. A DC powered computer system as described in claim 129 wherein said parametric regulation element comprises an element selected from a group consisting of a varactor capacitor, and a saturable inductor.

131. A DC powered computer system as described in claim 120 wherein said alternating input voltage regulator comprises a natural regulation network.

132. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. providing an alternating input at said electrically remote location;

f. regulating a voltage of said alternating input to control a component DC supply voltage;

g. transforming said alternating input at said electrically remote location to create a transformed alternating output;

h. rectifying said transformed alternating output at said electrically remote location to create said component DC supply voltage; and

i. powering said computer component from said component DC supply voltage.

133. A DC powered computer system comprising:

a. a utility power input which supplies AC utility power having a line frequency;

b. a line voltage rectifier element which converts said AC utility power to a DC signal;

c. an inverter element responsive to said DC signal which establishes an alternating power output;

d. a frequency driver which controls said inverter element to establish a distribution frequency;

e. a supply transformer element which is responsive to said alternating power output and which establishes at least one distribution output at at least one distribution voltage;

f. a power distribution system responsive to said supply transformer element and which provides computer components power at locations electrically remote from said inverter element;

g. at least voltage regulation module responsive to said power distribution system comprising:

1) at least one voltage regulation module rectifier element;

2) high voltage response circuitry to which said voltage regulation module rectifier element is responsive; and

3) a DC supply output responsive to said voltage regulation module rectifier element; and

h. at least one computer component responsive to said DC supply output.

134. A DC powered computer system as described in claim 133 wherein said voltage regulation module rectifier element has a non-conducting state and wherein said high voltage response circuitry to which said voltage regulation module rectifier element is responsive creates a high voltage one said voltage regulation module rectifier element when said voltage regulation module rectifier element is in said non-conducting state.

135. A DC powered computer system as described in claim 133 wherein said computer component responsive to said DC supply output comprises a low voltage, high current computer component.

136. A DC powered computer system as described in claim 135 wherein said voltage regulation module rectifier element comprises a switched voltage regulation module rectifier element.

137. A DC powered computer system as described in claim 136 wherein said low voltage, high current computer component comprises a low voltage, high current computer component operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

138. A DC powered computer system as described in claim 133 or 137 wherein said high voltage response circuitry subjects said voltage regulation module rectifier element to a voltage selected from a group consisting of at least about 1.4 times the voltage to which said first and said second voltage regulation module rectifier elements are subjected in a conducting state, at least about 8 times the voltage to which said first and said second voltage regulation module rectifier elements are subjected in a conducting state, at least about 15 volts, and at least about 20 volts when said first and said second voltage regulation module rectifier element is in a non-conducting state.

139. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. rectifying said power through at least one voltage regulation module rectifier element to establish a component DC supply voltage wherein said voltage regulation module rectifier element has a non-conducting

state;

f. subjecting said voltage regulation module rectifier element to a high voltage when said voltage regulation module rectifier element is in said non-conducting state; and

g. powering said computer component from said component DC supply voltage.

140. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. remotely rectifying said power with a rectifier frequency to establish a component DC supply voltage;

f. trapping a harmonic of said rectifier frequency; and

g. powering said computer component from said component DC supply voltage.

141. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the step of substantially eliminating transmission of at least one harmonic frequency.

142. A method of powering a DC computer system as described in claim 140 wherein said step of remotely rectifying said power with a rectifier frequency to establish a component DC supply voltage comprises the step of switching a rectifier element.

143. A method of powering a DC computer system as described in claim 142 wherein said step of switching a rectifier element comprises the steps of:

a. switching a first switched rectifier element; and

b. switching a second switched rectifier element.

144. A method of powering a DC computer system as described in claim 141 or 143 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location.

145. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the step of substantially eliminating forward transmission of at least one harmonic frequency.

146. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the step of substantially eliminating transmission of at least one even harmonic frequency.

147. A method of powering a DC computer system as described in claim 146 wherein said step of substantially eliminating transmission of at least one even harmonic frequency comprises the step of substantially eliminating transmission of at least a second harmonic frequency.

148. A method of powering a DC computer system as described in claim 147 wherein said step of switching a rectifier element comprises the steps of:

a. switching a first switched rectifier element; and

b. switching a second switched rectifier element,

wherein said first switched rectifier element and said second switched rectifier element are connected at a rectifier junction, and wherein said step of substantially eliminating transmission of at least a second harmonic frequency comprises the step of utilizing a parallel inductor and a parallel capacitor connected at said rectifier junction and tuned to said second harmonic frequency.

149. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the step of substantially eliminating backward transmission of at least one harmonic frequency.

150. A method of powering a DC computer system as described in claim 140 herein said step of trapping a harmonic of said rectifier frequency comprises the step of substantially eliminating transmission of at least one odd harmonic frequency.

151. A method of powering a DC computer system as described in claim 150 wherein said step of substantially eliminating transmission of at least one odd harmonic frequency comprises the step of substantially eliminating transmission of at least a third harmonic frequency.

152. A method of powering a DC computer system as described in claim 151 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location by a transformer having a primary side and wherein said step of substantially eliminating transmission of at least a third harmonic frequency comprises the step of acting upon said primary side of said transformer.

153. A method of powering a DC computer system as described in claim 152 wherein said step of substantially eliminating transmission of at least a third harmonic frequency further comprises the step of utilizing a series inductor and a series capacitor tied to said primary side of said transformer and tuned to said third harmonic frequency.

154. A method of powering a DC computer system as described in claim 151 wherein said step of switching a rectifier element comprises the steps of:

a. switching a first switched rectifier element to create a conduction state; and

b. switching a second switched rectifier element to create a conduction state while said first switched rectifier element is in a conduction state.

155. A method of powering a DC computer system as described in claim 151 wherein said step of switching a rectifier element comprises the steps of:

a. switching a first switched rectifier element which is responsive to a common alternating voltage source; and

b. switching a second switched rectifier element which is also responsive to said common alternating voltage source.

156. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the steps of:

a. substantially eliminating forward transmission of at least one harmonic frequency; and

b. substantially eliminating backward transmission of at least one harmonic frequency.

157. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the steps of:

a. substantially eliminating transmission of at least one even harmonic frequency; and

b. substantially eliminating transmission of at least one odd harmonic frequency.

158. A method of powering a DC computer system as described in claim 140 wherein said step of trapping a harmonic of said rectifier frequency comprises the steps of:

a. substantially eliminating transmission of at least a second harmonic frequency; and

b. substantially eliminating transmission of at least a third harmonic frequency.

159. A method of powering a DC computer system as described in claim 140 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location by a transformer having a primary side, wherein said step of switching a rectifier element comprises the steps of:

a. switching a first switched rectifier element; and

b. switching a second switched rectifier element,

wherein said first switched rectifier element and said second switched rectifier

element are connected at a rectifier junction, and wherein said step of trapping a harmonic of said rectifier frequency comprises the steps of:

a. utilizing a parallel inductor and a parallel capacitor connected at said rectifier junction; and

b. utilizing a series inductor and a series capacitor tied to said primary side of said transformer.

160. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. passively driving at least one switch to rectify said power and establish a component DC supply voltage; and

f. powering said computer component from said component DC supply voltage.

161. A method of powering a DC computer system as described in claim 160 wherein said step of rectifying said AC utility power to a DC signal comprises the steps of:

a. switching a first switched rectifier element; and

b. switching a second switched rectifier element.

162. A method of powering a DC computer system as described in claim 161 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location.

163. A method of powering a DC computer system as described in claim 160 wherein said step of passively driving at least one switch to rectify said power and establish a component DC supply voltage comprises the step of providing an alternating control input to at least one switch.

164. A method of powering a DC computer system as described in claim 162 and further comprising the step of transforming said alternating power output at said electrically remote location and wherein said step of passively driving at least one switch to rectify said power and establish a component DC supply voltage comprises the step of utilizing said alternating power output to drive said at least one switch.

165. A method of powering a DC computer system as described in claim 160 or 163 wherein said step of passively driving at least one switch to rectify said power and establish a component DC supply voltage comprises the step of providing a bias control input to at least one switch.

166. A method of powering a DC computer system as described in claim 165 and further comprising the step of transforming said alternating power output at said electrically remote location by a transformer having a secondary side and wherein said step of providing a bias control input to at least one switch comprises the step of electrically connecting said bias control input to said secondary side of said transformer.

167. A method of powering a DC computer system as described in claim 165 wherein said step of providing a bias control input to at least one switch comprises the step of providing a DC input.

168. A method of powering a DC computer system as described in claim 165 wherein said step of providing a bias control input to at least one switch comprises the step of providing a low frequency input.

169. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. switching a first switched rectifier element to create a first switched

rectifier output from said distributed power;

f. transmitting said first switched rectifier output through a first rectifier output inductance;

g. switching a second switched rectifier element to create a second switched rectifier output from said distributed power;

h. transmitting said second switched rectifier output through a second rectifier output inductance;

i coupling said first and second rectifier output inductances and thereby creating a component DC supply voltage; and

j. powering said computer component from said component DC supply voltage.

170. A method of powering a DC computer system as described in claim 169 wherein said step of coupling said first and second rectifier output inductances and thereby creating a component DC supply voltage comprises the step of magnetically coupling said first and second rectifier output inductances and thereby creating a component DC supply voltage.

171. A method of powering a DC computer system as described in claim 169 wherein said steps of transmitting said first switched rectifier output through a first rectifier output inductance and transmitting said second switched rectifier output through a second rectifier output inductance comprise the step of transmitting both said first switched rectifier output and said second switched rectifier output through a transformer.

172. A method of powering a DC computer system as described in claim 171 wherein said step of transmitting both said first switched rectifier output and said second switched rectifier output through a transformer comprises the step of transmitting both said first switched rectifier output and said second switched rectifier output through a one-to-one transformer.

173. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. establishing a component DC supply voltage;

f. transmitting said component DC supply voltage to an electrically remote computer component; and

g. powering said computer component from said component DC supply voltage.

174. A method of powering a DC computer system as described in claim 173 wherein said step of transmitting said component DC supply voltage to an electrically remote computer component comprises the step of transmitting said component DC supply voltage to over a distance selected from a group consisting of over at least about one-half inch, over at least about one inch, and over at least about two inches.

175. A method of powering a DC computer system as described in claim 173 wherein said step of transmitting said component DC supply voltage comprises the step of transmitting said component DC supply voltage at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

176. A method of powering a DC computer system as described in claim 173 or 175 wherein said step of transmitting a component DC supply voltage comprises the step of transmitting a component DC supply voltage through a DC output system capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

177. A method of powering a DC computer system as described in claim 173 or 175

wherein said step of transmitting a component DC supply voltage comprises the step of transmitting a component DC supply voltage through a DC output system operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

178. A method of powering a DC computer system as described in claim 173 wherein said step of transmitting said component DC supply voltage to an electrically remote computer component comprises the step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system.

179. A method of powering a DC computer system as described in claim 178 wherein said step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system comprises the step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

180. A method of powering a DC computer system as described in claim 173 and further comprising the step of electrically isolating said alternating power output prior to accomplishing said step of establishing a component DC supply voltage.

181. A method of powering a DC computer system as described in claim 180 wherein said step of electrically isolating said alternating power output comprises the step of transforming said alternating power output at said electrically remote location.

182. A method of powering a DC computer system as described in claim 181 wherein said

step of rectifying said AC utility power to a DC signal comprises the step of driving at least one rectifier element using a drive input and further comprising the step of electrically isolating said drive input at said electrically remote location.

183. A method of powering a DC computer system as described in claim 173, 174, or 178 wherein said step of distributing power to an electrically remote location comprises the step of utilizing substantially sinusoidal alternating signal power.

184. A method of powering a DC computer system as described in claim 183 wherein said step of utilizing substantially sinusoidal alternating signal power comprises the step of utilizing substantially sinusoidal alternating signal power operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHz, a frequency greater than at least about 3 MHz, a frequency greater than at least about 10 MHz, a frequency greater than at least about 30 MHz, a frequency coordinated with an inherent capacitance of a first and a second switched voltage regulation module rectifier, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of a sinusoidal drive system, and any permutations or combinations of the above.

185. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;
b. rectifying said AC utility power to a DC signal;
c. inverting said DC signal to establish an alternating power output;
d. distributing power to an electrically remote location;
e. activating a first rectifier element to create a conduction state;
f. activating a second rectifier element to create a conduction state while said first rectifier element is in a conduction state;
g. creating a component DC supply voltage as a result of said steps of activating said first and said second rectifier elements; and

h. powering said computer component from said component DC supply voltage.

186. A method of powering a DC computer system as described in claim 185 wherein said step of activating a second rectifier element to create a conduction state while said first rectifier element is in a conduction state comprises the step of causing conduction in both said first rectifier element and said second rectifier element to simultaneously occur at at least some time.

187. A method of powering a DC computer system as described in claim 185 wherein said step of activating a second rectifier element to create a conduction state while said first rectifier element is in a conduction state comprises the step of creating a conduction angle in each of said first and said second rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on said rectifier at the time when said rectifier transitions to said conduction state.

188. A method of powering a DC computer system as described in claim 185 or 187 and further comprising the step of subjecting said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state.

189. A method of powering a DC computer system as described in claim 188 wherein said step of subjecting said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state comprises the step of subjecting said first and said second rectifier elements to a voltage selected

from a group consisting of at least about 1.4 times the voltage to which said first and said second rectifier elements are subjected in a conducting state, at least about 8 times the voltage to which said first and said second rectifier elements are subjected in a conducting state. at least about 15 volts, and at least about 20 volts when said first and said second rectifier elements are in a non-conducting state.

190. A method of powering a DC computer system as described in claim 185 wherein said step of activating a first rectifier element comprises the step of switching a first switched rectifier element, and wherein said step of activating a second rectifier element comprises the step of switching a second switched rectifier element.

191. A method of powering a DC computer system as described in claim 185 wherein said step of activating a first rectifier element comprises the step of activating a first controllable diode element, and wherein said step of activating a second rectifier element comprises the step of activating a second controllable diode element.

192. A method of powering a DC computer system as described in claim 185 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location.

193. A method of regulating a DC voltage comprising the steps of:

a. activating a first rectifier element to create a conduction state;

b. activating a second rectifier element to create a conduction state while said first rectifier element is in a conduction state; and

c. creating a component DC supply voltage as a result of said steps of activating said first and said second rectifier elements.

194. A method of regulating a DC voltage as described in claim 193 werein said step of activating a second rectifier element to create a conduction state while said first rectifier element is in a conduction state comprises the step of causing conduction in both said first rectifier element and said second rectifier element to simultaneously

occur at at least some time.

195. A method of regulating a DC voltage as described in claim193 wherein said step of activating a first rectifier element comprises the step of switching a first switched rectifier element, and wherein said step of activating a second rectifier element comprises the step of switching a second switched rectifier element.

196. A method of regulating a DC voltage as described in claim 193 wherein said step of activating a first rectifier element comprises the step of activating a first controllable diode element, and wherein said step of activating a second rectifier element comprises the step of activating a second controllable diode element.

197. A method of regulating a DC voltage as described in claim 193 wherein said step of activating a second rectifier element to create a conduction state while said first rectifier element is in a conduction state comprises the step of creating a conduction angle in each of said first and said second rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on said rectifier at the time when said rectifier transitions to said conduction state.

198. A method of regulating a DC voltage as described in claim 193 or 197 and further comprising the step of subjecting said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state.

199 A method of regulating a DC voltage as described in claim 198 wherein said step of

subjecting said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state comprises the step of subjecting said first and said second rectifier elements to a voltage selected from a group consisting of at least about 1.4 times the voltage to which said first and said second rectifier elements are subjected in a conducting state, at least about 8 times the voltage to which said first and said second rectifier elements are subjected in a conducting state, at least about 15 volts, and at least about 20 volts when said first and said second rectifier elements are in a non-conducting state.

200. A method of regulating a DC voltage as described in claim 193 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location.

201. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. switching a first switched rectifier element responsive to said distributed power;

f. switching a second switched rectifier element responsive to said distributed power;

g. sinusoidally driving said first and said second switched rectifier elements to establish a component DC supply voltage; and

h. powering said computer component from said component DC supply voltage.

202. A method of powering a DC computer system as described in claim 201 and further comprising the step of transforming the power distributed to an electrically remote location at said electrically remote location.

203 A method of powering a DC computer system as described in claim 201 wherein said step of transforming the power distributed to an electrically remote location at said electrically remote location and said step of driving said first and said second switched rectifier elements to establish a component DC supply voltage each comprise the step of utilizing said distributed power.

204. A method of powering a DC computer system as described in claim 201 wherein said step of powering said computer component from said component DC supply voltage comprises powering said computer component from said component DC supply voltage through a substantially non-capacitive DC output system.

205. A method of powering a DC computer system as described in claim 204 wherein said step of powering said computer component from said component DC supply voltage through a substantially non-capacitive DC output system comprises the step of powering said computer component from said component DC supply voltage through a substantially non-capacitive DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

206. A method of powering a DC computer system as described in claim 201 and further comprising the step of electrically isolating said alternating power output prior to accomplishing said step of sinusoidally driving said first and said second switched rectifier elements to establish a component DC supply voltage.

207. A method of powering a DC computer system as described in claim 206 wherein said step of electrically isolating said alternating power output comprises the step of transforming said alternating power output at said electrically remote location.

208. A method of powering a DC computer system as described in claims 201 or 206 wherein said step of distributing power to an electrically remote location comprises the step of utilizing substantially sinusoidal alternating signal power.

209. A method of powering a DC computer system as described in claim 201 wherein said step of distributing power to an electrically remote location comprises the step of utilizing high frequency, substantially sinusoidal alternating signal power.

210. A method of powering a DC computer system as described in claim 209 wherein said step of utilizing high frequency, substantially sinusoidal alternating signal power comprises the step of utilizing high frequency, substantially sinusoidal alternating signal power operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHz, a frequency greater than at least about 3 MHz, a frequency greater than at least about 10 MHz, a frequency greater than at least about 30 MHz, a frequency coordinated with an inherent capacitance of a first and a second switched voltage regulation module rectifier, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of a sinusoidal drive system, and any permutations or combinations of the above.

211. A method of powering a DC computer system as described in claim 202 and further comprising the step of regulating said distributed power.

212. A method of powering a DC computer system as described in claim 211 wherein said step of regulating said distributed power also comprises the step of regulating said step of sinusoidally driving said first and said second switched rectifier elements to establish a component DC supply voltage.

213. A method of powering a DC computer system as described in claim 201 or 203

wherein said step of sinusoidally driving said first and said second switched rectifier elements to establish a component DC supply voltage comprises the step of establishing zero voltage switching.

214. A method of powering a DC computer system as described in claim 201 or 203 wherein said step of sinusoidally driving said first and said second switched rectifier elements to establish a component DC supply voltage comprises the step of providing a bias input.

215. A method of powering a DC computer system as described in claim 214 wherein said step of providing a bias input comprises the step of providing a DC input.

216. A method of powering a DC computer system as described in claim 214 wherein said step of providing a bias input comprises the step of providing a low frequency input.

217. A method of powering a DC computer system as described in claim 214 wherein said step of providing a bias input comprises the step of biasing a rectifier control transformer.

218. A method of regulating a DC voltage comprising the steps of:

a. supplying an alternating input;

b. transforming said alternating input;

c. rectifying said alternating input to establish a DC supply voltage;

d. transmitting said DC supply voltage through a substantially non-capacitive DC output system.

219. A method of powering a DC computer system as described in claim 218 wherein said step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system comprises the step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system having an effective capacitance selected from a group consisting of less than about 0.3

millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads. less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

220. A method of powering a DC computer system as described in claim 218 wherein said step of rectifying said alternating input to establish a DC supply voltage comprises the steps of:

a. switching a first switched rectifier element; and

b. switching a second switched rectifier element.

221. A method of powering a DC computer system as described in claim 218 wherein said step of supplying an alternating input comprises the step of providing a high frequency, substantially sinusoidal alternating input.

222. A method of powering a DC computer system as described in claim 218 wherein said step of providing a high frequency, substantially sinusoidal alternating input comprises the step of providing a high frequency, substantially sinusoidal alternating input operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHz, a frequency greater than at least about 3 MHz, a frequency greater than at least about 10 MHz, a frequency greater than at least about 30 MHz, a frequency coordinated with an inherent capacitance of a first and a second switched voltage regulation module rectifier, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of a sinusoidal drive system, and any permutations or combinations of the above.

223. A method of powering a DC computer system as described in claim 218 wherein said

step of transmitting a component DC supply voltage comprises the step of transmitting a component DC supply voltage at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

224. A method of powering a DC computer system as described in claim 218 wherein said step of transmitting a component DC supply voltage through a substantially non-capacitive DC output system comprises the step of transmitting a component DC supply voltage through a DC output system capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

225. A method of powering a DC computer system as described in claim 218 wherein said step of transmitting a component DC supply voltage through a substantially non-capacitive DC output system comprises the step of transmitting a component DC supply voltage through a DC output system operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

226. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. providing an alternating input at said electrically remote location;

f. transforming said alternating input at said electrically remote location to create a a transformed alternating output;

g. rectifying said transformed alternating output at said electrically remote location to create a component DC supply voltage;

h. transmitting said component DC supply voltage through a substantially non-capacitive DC output system; and

i. powering said computer component from said component DC supply voltage.

227. A method of powering a DC computer system as described in claim 226 wherein said step of powering said computer component from said component DC supply voltage comprises the step of powering a low voltage, high current computer component from said component DC supply voltage.

228. A method of powering a DC computer system as described in claim 226 wherein said step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system comprises the step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system having an effective capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of said computer component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

229. A method of powering a DC computer system as described in claim 226 wherein said step of rectifying said AC utility power to a DC signal comprises the steps of:

a. switching a first switched rectifier element; and

b. switching a second switched rectifier element.

230. A method of powering a DC computer system as described in claim 226 wherein said step of providing an alternating input at said electrically remote location comprises the step of providing a high frequency, substantially sinusoidal alternating input.

231. A method of powering a DC computer system as described in claim 230 wherein said

step of providing a high frequency, substantially sinusoidal alternating input comprises the step of providing a high frequency, substantially sinusoidal alternating input operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHz, a frequency greater than at least about 3 MHz, a frequency greater than at least about 10 MHz, a frequency greater than at least about 30 MHz, a frequency coordinated with an inherent capacitance of a first and a second switched voltage regulation module rectifier, a frequency coordinated with an inherent capacitance of said computer component, a frequency coordinated with an inherent capacitance of a component connector, a frequency coordinated with an inherent capacitance of a sinusoidal drive system, and any permutations or combinations of the above.

232. A method of powering a DC computer system as described in claim 226 wherein said step of transmitting said component DC supply voltage comprises the step of transmitting said component DC supply voltage at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

233. A method of powering a DC computer system as described in claim 226 wherein said step of transmitting said component DC supply voltage through a substantially non-capacitive DC output system comprises the step of transmitting said component DC supply voltage through a DC output system capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

234. A method of powering a DC computer system as described in claim 226 wherein said step of transmitting said component DC supply voltage through a substantially non-

capacitive DC output system comprises the step of transmitting said component DC supply voltage through a DC output system operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

235. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. providing an alternating input at said electrically remote location;

f. regulating a voltage of said alternating input to control a component DC supply voltage;

g. transforming said alternating input at said electrically remote location to create a a transformed alternating output;

h. rectifying said transformed alternating output at said electrically remote location to create said component DC supply voltage; and

i. powering said computer component from said component DC supply voltage.

236 A method of powering a DC computer system as described in claim 235 wherein said step of transforming said alternating input is accomplished by a transformer element having a primary side and wherein said step of regulating a voltage of said alternating input to control a component DC supply voltage comprises the step of regulating a voltage provided to said primary side of said transformer element.

237. A method of powering a DC computer system as described in claim 236 wherein said step of regulating a voltage of said alternating input comprises the step of varying a capacitor.

238. A method of powering a DC computer system as described in claim 236 wherein said

step of regulating a voltage of said alternating input comprises the step of utilizing a series switch element.

239. A method of powering a DC computer system as described in claim 238 wherein said step of utilizing a series switch element comprises the step of utilizing two series switch elements.

240. A method of powering a DC computer system as described in claim 236 wherein said step of regulating a voltage of said alternating input comprises the step of utilizing an electrical isolation element.

241. A method of powering a DC computer system as described in claim 324 wherein said step of utilizing two series switch elements comprises the step of driving said switches at about a 180 degree phase relationship.

242. A method of powering a DC computer system as described in claim 235 werein said step of regulating a voltage of said alternating input comprises the step of utilizing a linear regulation element.

243. A method of powering a DC computer system as described in claim 242 wherein said step of utilizing a linear regulation element comprises the step of utilizing a linear regulation element which is a variable linear capacitor or a variable linear inductor.

244. A method of powering a DC computer system as described in claim 235 wherein said step of regulating a voltage of said alternating input comprises the step of parametrically regulating.

245. A method of powering a DC computer system as described in claim 244 wherein said step of parametrically regulating comprises the step of utilizing a parametric regulation element which is a varactor capacitor or a saturable inductor.

246. A method of powering a DC computer system as described in claim 235 wherein said step of regulating a voltage of said alternating input comprises the naturally regulating.

247. A method of powering a DC computer system comprising the steps of:

a. supplying an AC utility power having a line frequency;

b. rectifying said AC utility power to a DC signal;

c. inverting said DC signal to establish an alternating power output;

d. distributing power to an electrically remote location;

e. rectifying said power through at least one voltage regulation module rectifier element to establish a component DC supply voltage wherein said voltage regulation module rectifier element has a non-conducting state;

f. subjecting said voltage regulation module rectifier element to a high voltage when said voltage regulation module rectifier element is in said non-conducting state; and

g. powering said computer component from said component DC supply voltage.

248. A method of powering a DC computer system as described in claim 247 wherein said step of powering said computer component from said component DC supply voltage comprises the step of powering a low voltage, high current computer component from said component DC supply voltage.

249. A method of powering a DC computer system as described in claim 248 wherein said step of rectifying said power through at least one voltage regulation module rectifier element to establish a component DC supply voltage wherein said voltage regulation module rectifier element has a non-conducting state comprises the step of switching a rectifier element.

250. A method of powering a DC computer system as described in claim 249 wherein said

step of powering said computer component from said component DC supply voltage comprises the step of powering said computer component from said component DC supply voltage at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

251. A method of powering a DC computer system as described in claims 247 or 250 wherein said step of subjecting said voltage regulation module rectifier element to a high voltage when said voltage regulation module rectifier element is in said non-conducting state comprises the step of subjecting said voltage regulation module rectifier element to a voltage selected from a group consisting of at least about 1.4 times the voltage to which said voltage regulation module rectifier element is subjected in a conducting state, at least about 8 times the voltage to which said voltage regulation module rectifier element is subjected in a conducting state, at least about 15 volts, and at least about 20 volts when said voltage regulation module rectifier element is in a non-conducting state.

252. Methods substantially as described hereinbefore and with reference to any of the accompanying examples.

253. Apparatuses substantially as described hereinbefore and with reference to any of the accompanying examples.

rectifier control system to which said first and said second rectifier elements are responsive causes conduction in both said first rectifier element and said second rectifier element to simultaneously occur at least some time.

256. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element.

257. A rectification circuit as described in claim 254 wherein said first rectifier element comprises a first controllable diode element and wherein said second rectifierelement comprises a second controllable diode element.

258. A rectification circuit as described in claim 254 wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which is less than about 1.5 as compared to a DC output current, and a conduction angle which creates zero voltage on each said rectifier at the time when said rectifier is switched to a conductive state.

259. A rectification circuit as described in claim 254 or 258 wherein said rectification circuit further comprises high voltage response circuitry which subjects said first and said second rectifier elements to a high voltage when said first and said second rectifier elements are in a non-conducting state.

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260. A rectification circuit as described in claim 259 wherein said high voltage response circuitry subjects said first and said second rectifier elements to a voltage selected from a group consisting of at least about 1.4 times a DC output voltage, at least about 8 times a DC output voltage, at least about 15 volts, and at least about 20 volts.

261. A rectification circuit as described in claim 254 and further comprising a transformer element to which said first and said second rectifier elements are responsive.

262. A rectification circuit as described in claim 261 and further comprising a total capacitance and a transformer leakage inductance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and said total capacitance are coordinated with said transformer leakage inductance.

263. A rectification circuit as described in claim 262 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier elementcomprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

264. A rectification circuit as described in claim 261 and further comprising a transformer leakage inductance, wherein said rectification circuit affirmatively utilizes said transformer leakage inductance as an energy storage element.

265. A rectification circuit as described in claim 264 and further comprising a total capacitance and wherein said overlapping conduction rectifier control system to which said first and said second rectifier elements are responsive comprises an overlapping conduction rectifier control system configured to create a conduction angle in each of said first and said second rectifier elements, wherein said conduction angles and

said total capacitance are coordinated with said transformer leakage inductance.

266. A rectification circuit as described in claim 265 wherein said first rectifier element comprises a first switched rectifier element and wherein said second rectifier element comprises a second switched rectifier element such that said conduction angles and said total capacitance are coordinated with said transformer leakage inductance to create zero voltage on each said switched rectifier element at the time when each said rectifier is switched to a conductive state.

267. A method of current rectification, comprising the steps of:

a. providing a first rectifier element and a second rectifier element;

b. providing an AC input to said first and second rectifier elements;

c. controlling overlapping conduction of said first and said second rectifier elements; and

d. producing a DC output.

268. A power supply circuit powering a microprocessor capable of a rapid current demand comprising a DC power supply physically remote from said microprocessor.

269. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said microprocessor comprises a low voltage, high current load and wherein said DC power supply provides a regulated voltage to said load.

270. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said DC power supply provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said DC power supply to said microprocessor, over at least about one inch from said DC power supply to said microprocessor, and over at least about two inches from said DC power supply to said microprocessor.

271. A remote power supply circuit powering a microprocessor capable of a rapid current

demand as described in claim 268 wherein said power supply is electrically remote from said microprocessor.

272. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 further comprising a bypass capacitance adjacent said microprocessor.

273. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 272 wherein said bypass capacitance comprises a total bypass capacitance selected from the group consisting of less than about .2 millifarads and less than about .5 millifarads.

274. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 272 wherein said bypass capacitance comprises a capacitance selected from the group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

275. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said DC power supply comprises a substantially non-capacitive output.

276. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 275 wherein said DC power supply comprises a substantially inductive output.

277. A remote power supply circuit powering a microprocessor capable of a rapidcurrent demand as described in claim 269 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting

of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

278. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 269 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

279. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 269 wherein said microprocessor comprises a microprocessor operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

280. A remote power supply circuit powering a microprocessor capable of a rapid current demand as described in claim 268 wherein said DC power supply comprises a voltage regulation module.

281. A method of powering a microprocessor capable of a rapid current demand, comprising the steps of:

a. establishing a DC power supply physically remote from said microprocessor; and

b. remotely powering said microprocessor.

282. A power supply circuit powering a low voltage, high current microprocessor capable of a rapid current demand comprising a DC power supply having a substantially inductive DC output.

283. A power supply circuit powering a microprocessor as described in claim 282 wherein said microprocessor comprises a low voltage, high current load and wherein said DC

power supply provides a regulated voltage to said load.

284. A power supply circuit powering a microprocessor as described in claim 282 wherein said DC power supply is physically remote from said microprocessor.

285. A power supply circuit powering a microprocessor as described in claim 284 wherein said DC power supply provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said DC power supply to said microprocessor, over at least about one inch from said DC power supply to said microprocessor, and over at least about two inches from said DC power supply to said microprocessor.

286. A power supply circuit powering a microprocessor as described in claim 282 wherein said DC power supply is electrically remote from said microprocessor.

287. A power supply circuit powering a microprocessor as described in claim 282 further comprising a bypass capacitance adjacent said microprocessor.

288. A power supply circuit powering a microprocessor as described in claim 287 wherein said bypass capacitance comprises a total bypass capacitance selected from a group consisting of less than about .2 millifarads and less than about .5 millifarads.

289. A power supply circuit powering a microprocessor as described in claim 287 wherein said bypass capacitance comprises a capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

290. A power supply circuit powering a microprocessor as described in claim 282 wherein

said substantially inductive DC output comprises a substantially non-capacitive output.

291. A power supply circuit powering a microprocessor as described in claim 283 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

292. A power supply circuit powering a microprocessor as described in claim 283 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

293. A power supply circuit powering a microprocessor as described in claim 283 wherein said microprocessor comprises a microprocessor operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

294. A power supply circuit powering a microprocessor as described in claim 282 wherein said DC power supply comprises a voltage regulation module.

295. A method of powering a low voltage, high current microprocessor capable of a rapid current demand, comprising the steps of:

a. providing a DC power supply having a substantially inductive DC output; and
b. powering said microprocessor with said substantially inductive DC output.

296. A power supply circuit powering a low voltage, high current microprocessor capable of a rapid current demand comprising a voltage regulation module having a substantially non-capacitive DC output.

297. A power supply circuit powering a microprocessor as described in claim 296 wherein said microprocessor comprises a low voltage, high current load and wherein said voltage regulation module provides a regulated voltage to said load.

298. A power supply circuit powering a microprocessor as described in claim 296 wherein said voltage regulation module is physically remote from said microprocessor.

299. A power supply circuit powering a microprocessor as described in claim 298 wherein said voltage regulation module provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said voltage regulation module to said microprocessor, over at least about one inch from said voltage regulation module to said microprocessor, and over at least about two inches from said voltage regulation module to said microprocessor.

300. A power supply circuit powering a microprocessor as described in claim 296 wherein said voltage regulation module is electrically remote from said microprocessor.

301. A power supply circuit powering a microprocessor as described in claim 296 further comprising a bypass capacitance adjacent said microprocessor.

302. A power supply circuit powering a microprocessor as described in claim 301 wherein said bypass capacitance comprises a total bypass capacitance selected from a group consisting of less than about .2 millifarads and less than about .5 millifarads.

303. A power supply circuit powering a microprocessor as described in claim 301 wherein said bypass capacitance comprises a capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

304. A power supply circuit powering a microprocessor as described in claim 296 wherein said substantially non-capacitive DC output comprises a subtantially inductive DC output.

305. A power supply circuit powering a microprocessor as described in claim 304 wherein a subtantially inductive DC output comprises an inductance internal to said voltage regulation module.

306. A power supply circuit powering a microprocessor as described in claim 305 wherein said inductance internal to said voltage regulation module comprises an inductance selected from a group consisting of a total series inductance and an interconnect inductance.

307. A power supply circuit powering a microprocessor as described in claim 304 or 305 wherein said substantially inductive DC output comprises an inductance external to said voltage regulation module.

308. A power supply circuit powering a microprocessor as described in claim 297 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

309. A power supply circuit powering a microprocessor as described in claim 297 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

310. A power supply circuit powering a microprocessor as described in claim 297 wherein said microprocessor comprises a microprocessor operating at a maximum current

selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

311. A method of powering a low voltage, high current microprocessor capable of a rapid current demand, comprising the steps of:

a. providing a voltage regulation module having a substantially non-capacitive DC output; and

b. powering said microprocessor with said substantially non-capacitive DC output.

312. A power supply circuit powering a low voltage, high current microprocessor capable of a rapid current demand comprising a voltage regulation module having a substantially inductive DC output.

313. A power supply circuit powering a microprocessor as described in claim 312 wherein said microprocessor comprises a low voltage, high current load and wherein said voltage regulation module provides a regulated voltage to said load.

314. A power supply circuit powering a microprocessor as described in claim 312 wherein said voltage regulation module is physically remote from said microprocessor.

315. A power supply circuit powering a microprocessor as described in claim 314 wherein said voltage regulation module provides said microprocessor power remotely over a distance selected from a group consisting of over at least about one-half inch from said voltage regulation module to said microprocessor, over at least about one inch from said voltage regulation module to said microprocessor, and over at least about two inches from said voltage regulation module to said microprocessor.

316. A power supply circuit powering a microprocessor as described in claim 312 wherein said voltage regulation module is electrically remote from said microprocessor.

317. A power supply circuit powering a microprocessor as described in claim 312 further

comprising a bypass capacitance adjacent said microprocessor.

318. A power supply circuit powering a microprocessor as described in claim 317 wherein said bypass capacitance comprises a total bypass capacitance selected from a group consisting of less than about .2 millifarads and less than about .5 millifarads.

319. A power supply circuit powering a microprocessor as described in claim 317 wherein said bypass capacitance comprises a capacitance selected from a group consisting of less than about 0.3 millifarads, less than about 0.5 millifarads, less than about 1 millifarads, less than about 3 millifarads, less than about 10 millifarads, about only the inherent capacitance of a response network, about only an inherent reactance of a component connector, about only an inherent capacitance of a low voltage, high current component, about only a bypass capacitance of a microprocessor, and any permutations or combinations of the above.

320. A power supply circuit powering a microprocessor as described in claim 312 wherein said substantially inductive DC output comprises a substantially non-capacitive DC output.

321. A power supply circuit powering a microprocessor as described in claims 312 wherein said substantially inductive DC output comprises an inductance internal to said voltage regulation module.

322. A power supply circuit powering a microprocessor as described in claim 321 wherein said inductance internal to said voltage regulation module comprises an inductance selected from a group consisting of a total series inductance and an interconnect inductance.

323. A power supply circuit powering a microprocessor as described in claims 312 or 321 wherein said substantially inductive DC output comprises an inductance external to said voltage regulation module.

324. A power supply circuit powering a microprocessor as described in claim 313 wherein said microprocessor comprises a microprocessor operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

325. A power supply circuit powering a microprocessor as described in claim 313 wherein said microprocessor is capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

326. A power supply circuit powering a microprocessor as described in claim 313 wherein said microprocessor comprises a microprocessor operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

327. A method of powering a low voltage, high current microprocessor capable of a rapid current demand, comprising the steps of:

a. providing a voltage regulation module having a substantially inductive DC output; and

b. powering said microprocessor with said substantially inductive DC output.

328. A rectification circuit comprising:

a. a first rectifier element;

b. a second rectifier element;

c. a passive sinusoidal drive system to which said first rectifier element and said second rectifier element are responsive; and

d. a DC output responsive to said first rectifier element and said second rectifier element.

329. A rectification circuit as described in claim 328 and further comprising a synchronous rectifier control system to which said first and second rectifier elements are responsive.

330. A rectification circuit as described in claim 328 wherein said passive sinusoidal drive system comprises a gate drive transformer element.

331. A rectification circuit as described in claim 328 wherein said sinusoidal drive system to which said first and second rectifier elements are responsive comprises a high frequency sinusoidal drive system.

332. A rectification circuit as described in claim 331 wherein said high frequency sinusoidal drive system comprises a drive system operating at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ, a frequency coordinated with an inherent capacitance of said first and second synchronous rectifier elements, and any permutations or combinations of the above.

333. A rectification circuit as described in claim 329 wherein said synchronous rectifier control system comprises a bias input.

334. A rectification circuit as described in claim 333 wherein said bias input comprises a DC input.

335. A rectification circuit as described in claim 333 wherein said bias input comprises a low frequency input.

336. A rectification circuit as described in claim 334 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said DC input.

337. A rectification circuit as described in claim 335 wherein each of said first and second synchronous rectifier elements comprise a conduction angle responsive to said low frequency input.

338. A method of current rectification, comprising the steps of:
   a. providing a first rectifier synchronous element and a second synchronous rectifier element;
   b. providing an AC input to said first and second synchronous rectifier elements;
   c. passively sinusoidally driving said first and said second synchronous rectifier elements; and
   d. producing a DC output.

339. An AC to DC conversion system comprising:
   a. an AC input;
   b. a rectification circuit having a total capacitance; and
   c. a DC output;

wherein said conversion system affirmatively utilizes said total capacitance of said rectification circuit.

340. An AC to DC conversion system as described in claim 339 wherein said rectification circuit comprises at least two rectifier elements.

341. An AC to DC conversion system as described in claim 340 wherein said at least two rectifier elements each comprise a Field Effect Transistor.

342. An AC to DC conversion system as described in claim 341 wherein said total capacitance of said rectification circuit comprises an adjunct drain-to-source capacitance of each Field Effect Transistor.

343. An AC to DC conversion system as described in claim 342 wherein said total capacitance of said rectification circuit further comprises circuit capacitance additional to said adjunct drain to source capacitance of each Field Effect Transistor.

344. An AC to DC conversion system as described in claim 340 wherein said at least two rectifier elements each comprise a synchronous rectifier element.

345. An AC to DC conversion system as described in claim 344 wherein said total capacitance of said rectification circuit comprises an adjunct capacitance of each synchronous rectifier element.

346. An AC to DC conversion system as described in claim 345 wherein said total capacitance of said rectification circuit further comprises circuit capacitance additional to said adjunct capacitance of each synchronous rectifier element.

347. An AC to DC conversion system as described in claim 345 wherein said conversion system affirmatively utilizes said adjunct capacitance of each said synchronous rectifier element to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

348. An AC to DC conversion system as described in claim 344 wherein said conversion system operates at a power conversion frequency and wherein said conversion system affirmatively utilizes said power conversion frequency to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

349. An AC to DC conversion system as described in claim 348 wherein said conversion system operates at a frequency selected from a group consisting of a frequency greater than at least about 300 kHz, a frequency greater than at least about 500 kHz, a frequency greater than at least about 1 MHZ, a frequency greater than at least about 3 MHZ, a frequency greater than at least about 10 MHZ, a frequency greater than at least about 30 MHZ.

350. An AC to DC conversion system as described in claim 344 and further comprising an overlapping conduction rectifier control system and wherein said conversion system affirmatively utilizes a conduction angle of each said synchronous rectifier element

to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

351. An AC to DC conversion system as described in claim 350 wherein said conduction angle of each of said at least two rectifier elements is selected from a group consisting of at least about 180 degrees, at least about 300 degrees, a conduction angle which creates a low rectifier RMS current, a conduction angle which creates a rectifier RMS current which is low as compared to an output current, a conduction angle which creates a rectifier RMS current which less than about 1.3 as compared to a DC output current, a conduction angle which creates a rectifier RMS current which less than about 1.4 as compared to a DC output current, and a conduction angle which creates a rectifier RMS current which is less than about 1.5 as compared to a DC output current.

352. An AC to DC conversion system as described in claim 344 and further comprising a transformer element and wherein said conversion system affirmatively utilizes a transformer leakage inductance of said transformer element to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

353. An AC to DC conversion system as described in claim 344 wherein said coversion system affirmatively coordinates a power conversion frequency of said conversion system, a conduction angle of each said synchronous rectifier element, a transformer leakage inductance of said conversion system, and said total capacitance to create zero voltage on each said synchronous rectifier element prior to a switched conductive state of each said synchronous rectifier element.

354. An AC to DC conversion system as described in claim 339 wherein said DC output powers a low voltage, high current component operating at a nominal DC voltage selected from a group consisting of less than about 2 volts, less than about 1.8 volts, less than about 1.5 volts, less than about 1.3 volts, less than about 1 volt, and less than about 0.4 volts.

355. An AC to DC conversion system as described in claim 339 wherein said DC output powers a low voltage, high current component capable of a rapid current demand which rises at a level selected from a group consisting of at least about 0.2 amperes per nanosecond, at least about 0.5 amperes per nanosecond, at least about 1 ampere per nanosecond, at least about 3 amperes per nanosecond, at least about 10 amperes per nanosecond, and at least about 30 amperes per nanosecond.

356. An AC to DC conversion system as described in claim 339 wherein said DC output powers a low voltage, high current component operating at a maximum current selected from a group consisting of more than about 15 amperes, more than about 20 amperes, more than about 50 amperes, and more than about 100 amperes.

357. A method of AC to DC conversion, comprising the steps of:

a. providing a rectification circuit having a total capacitance;

b. providing an AC input to said rectification circuit;

c. affirmatively utilizing said total capacitance of said rectification circuit; and

d. producing a DC output.

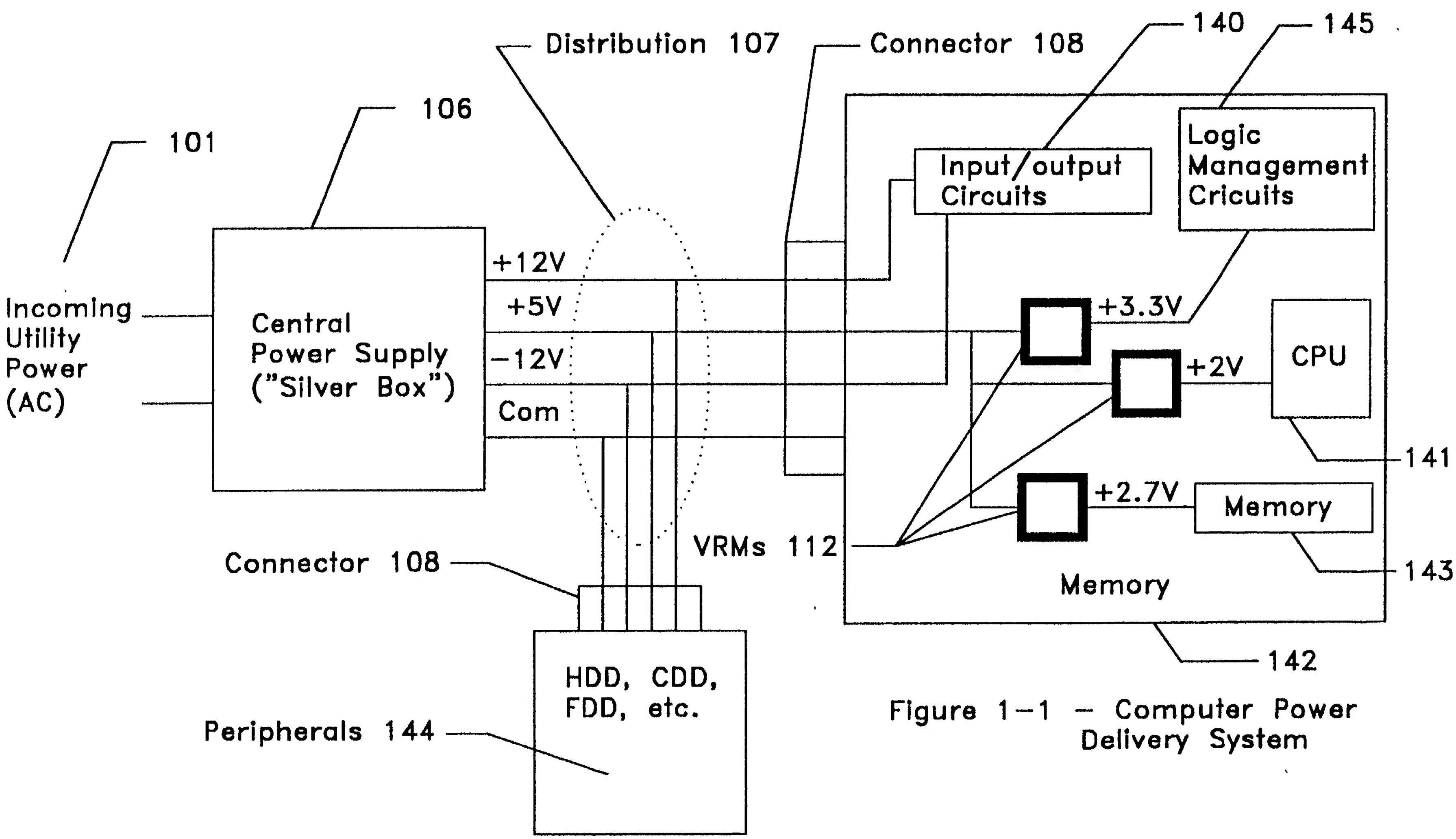

Figure 1−1 − Computer Power Delivery System

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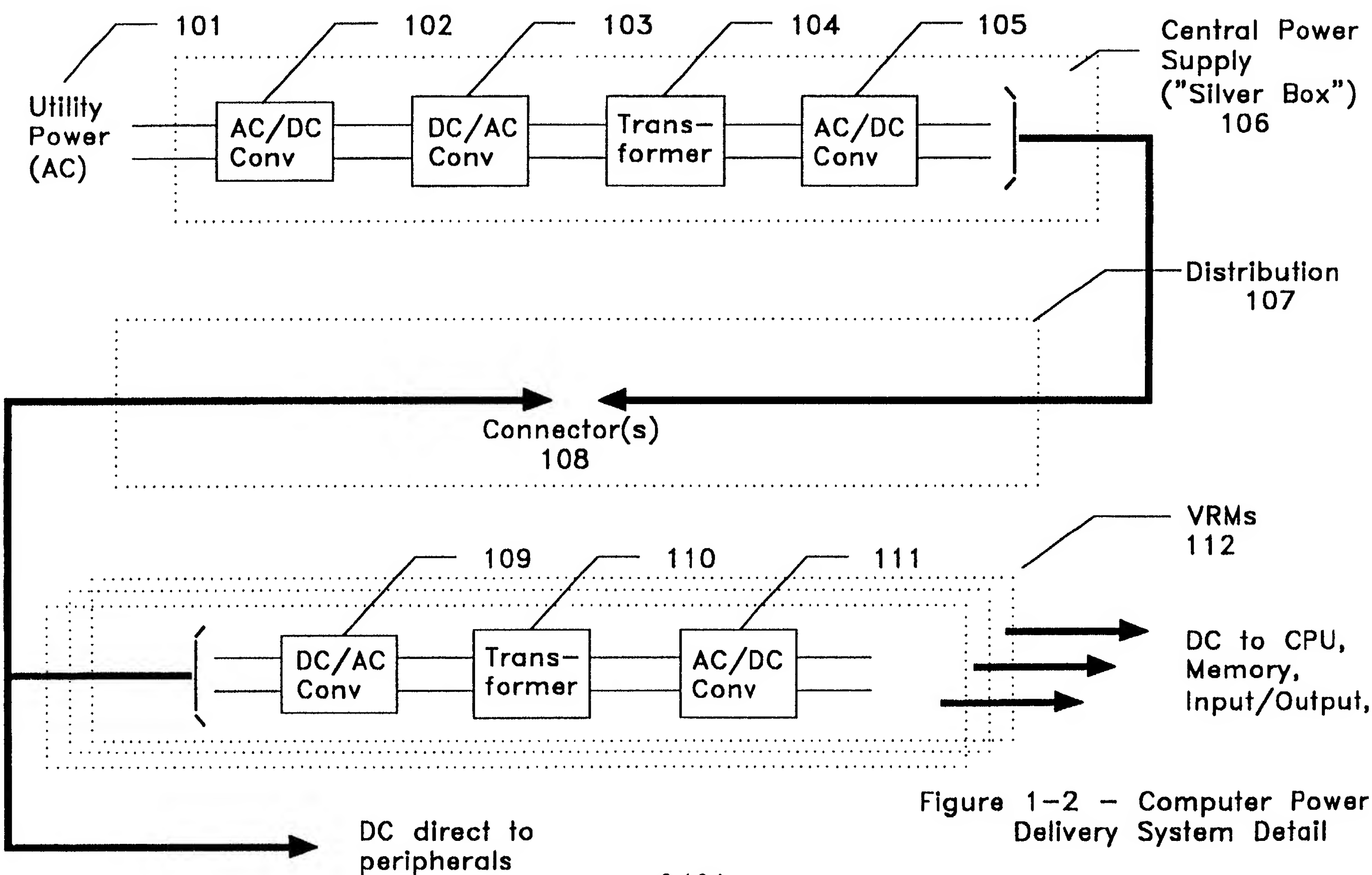

Figure 1-2 - Computer Power Delivery System Detail

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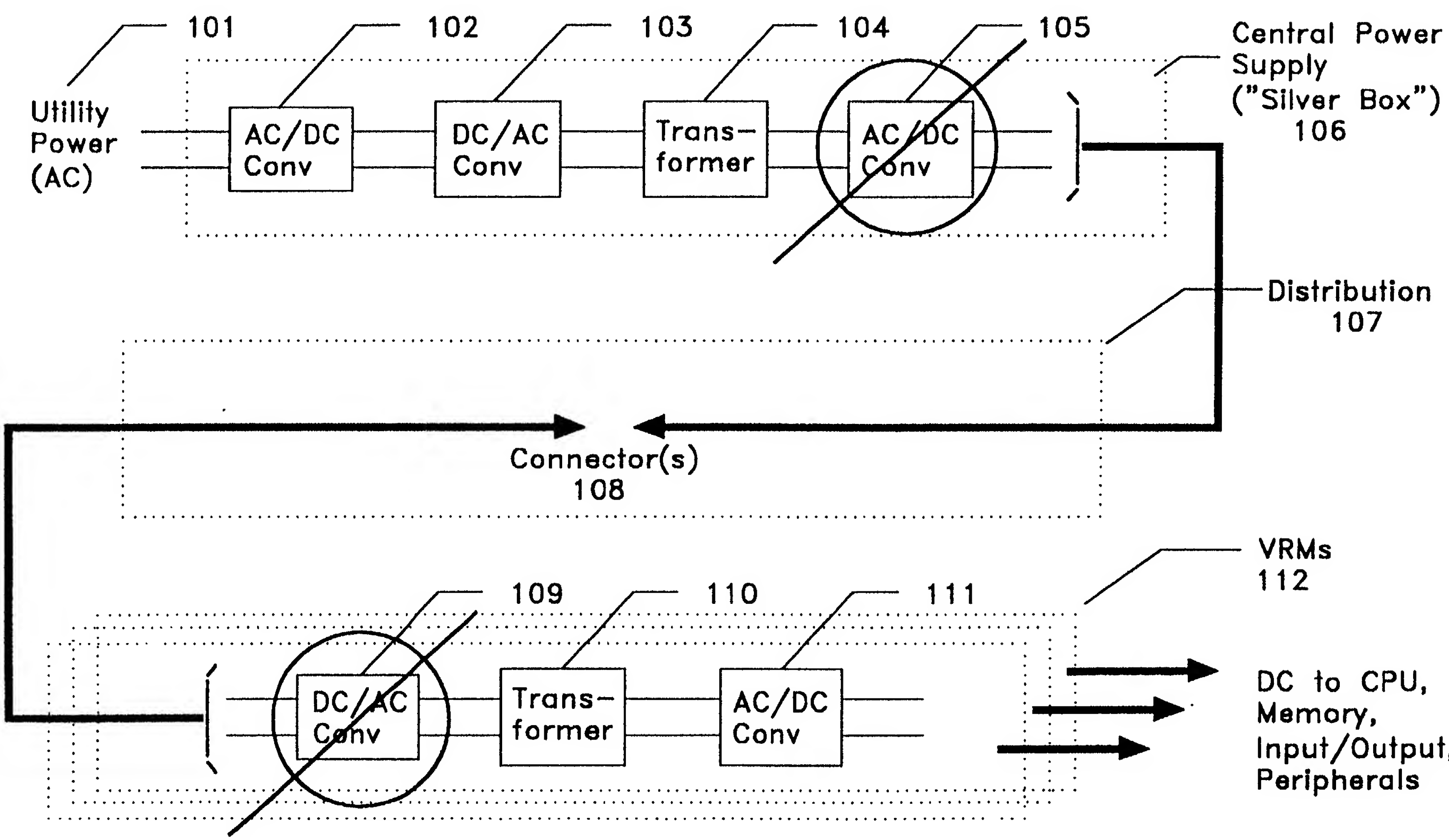


Figure 1-3 – Components eliminated by invention

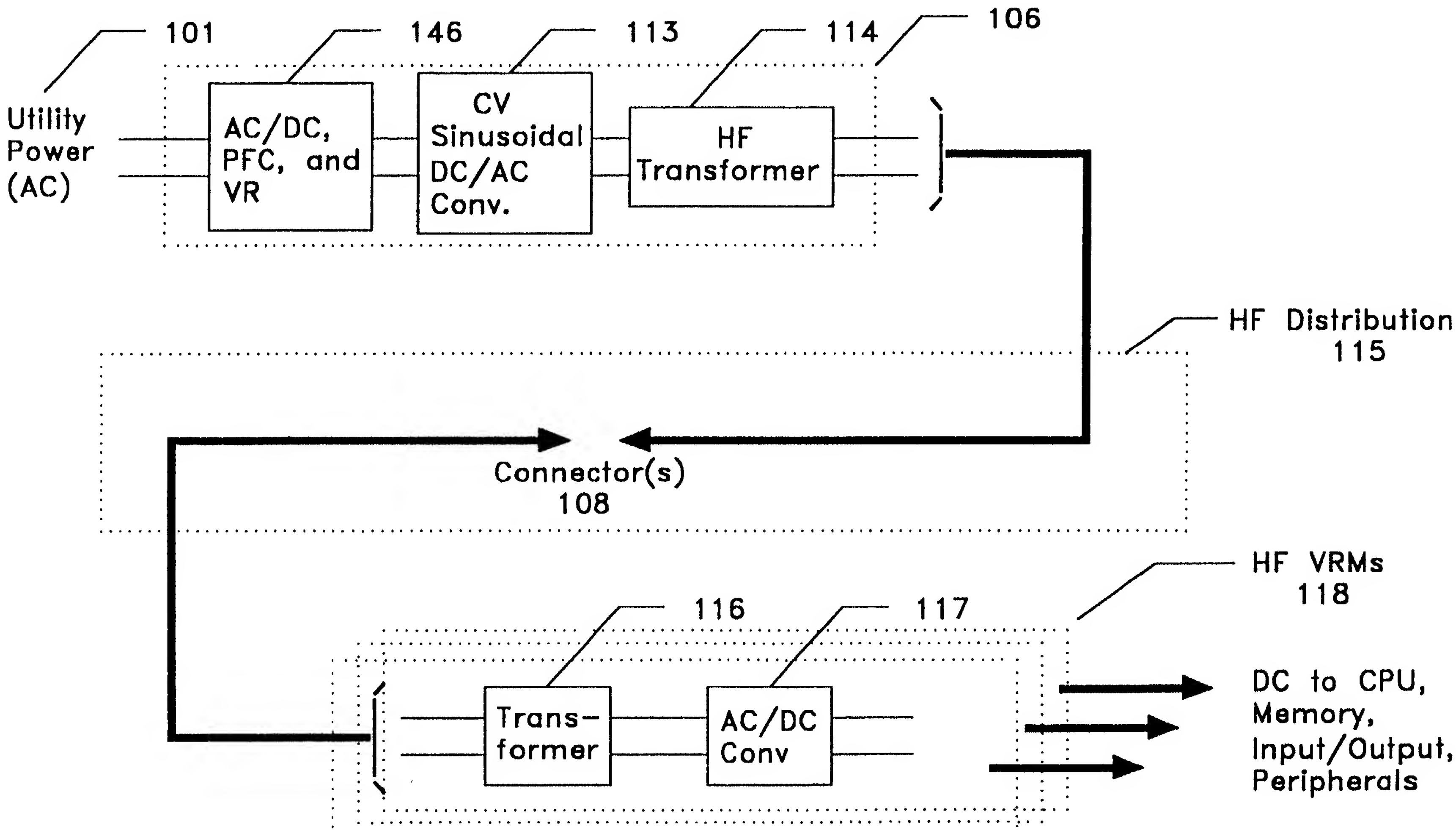


Figure 1-4 – HFAC Power System

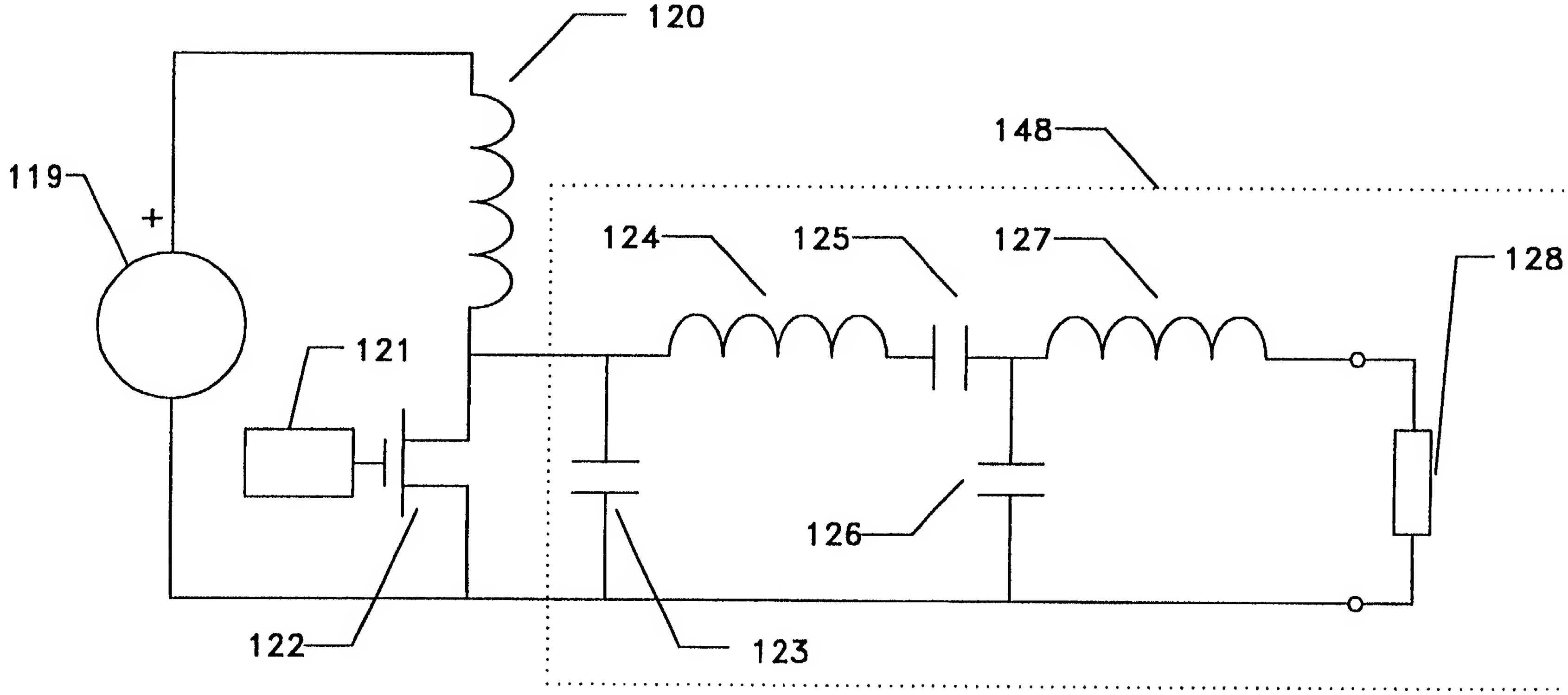


Figure 1–5 – High Frequency CV Generator – non-resonant

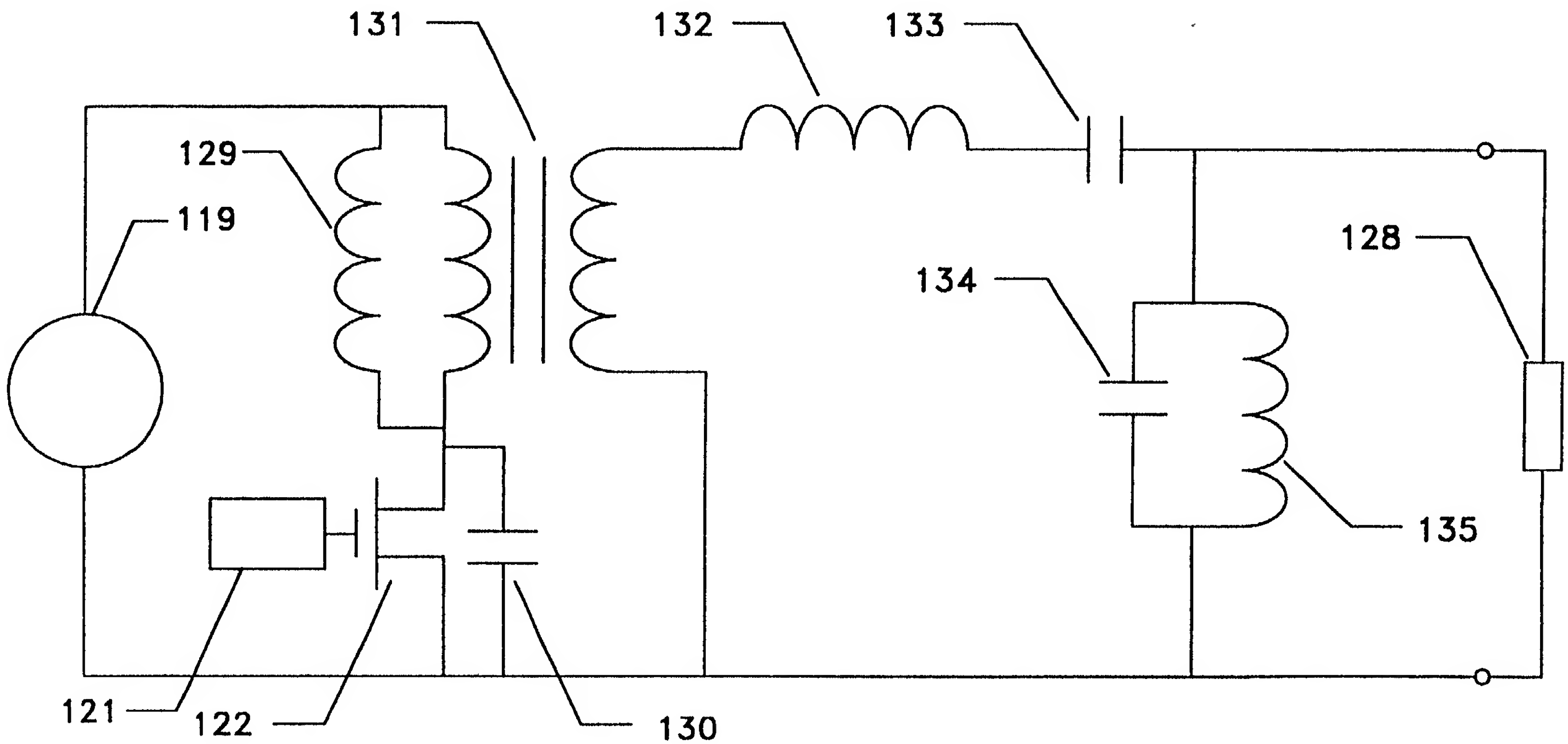


Figure 1–6 – High Frequency CV Generator – resonant

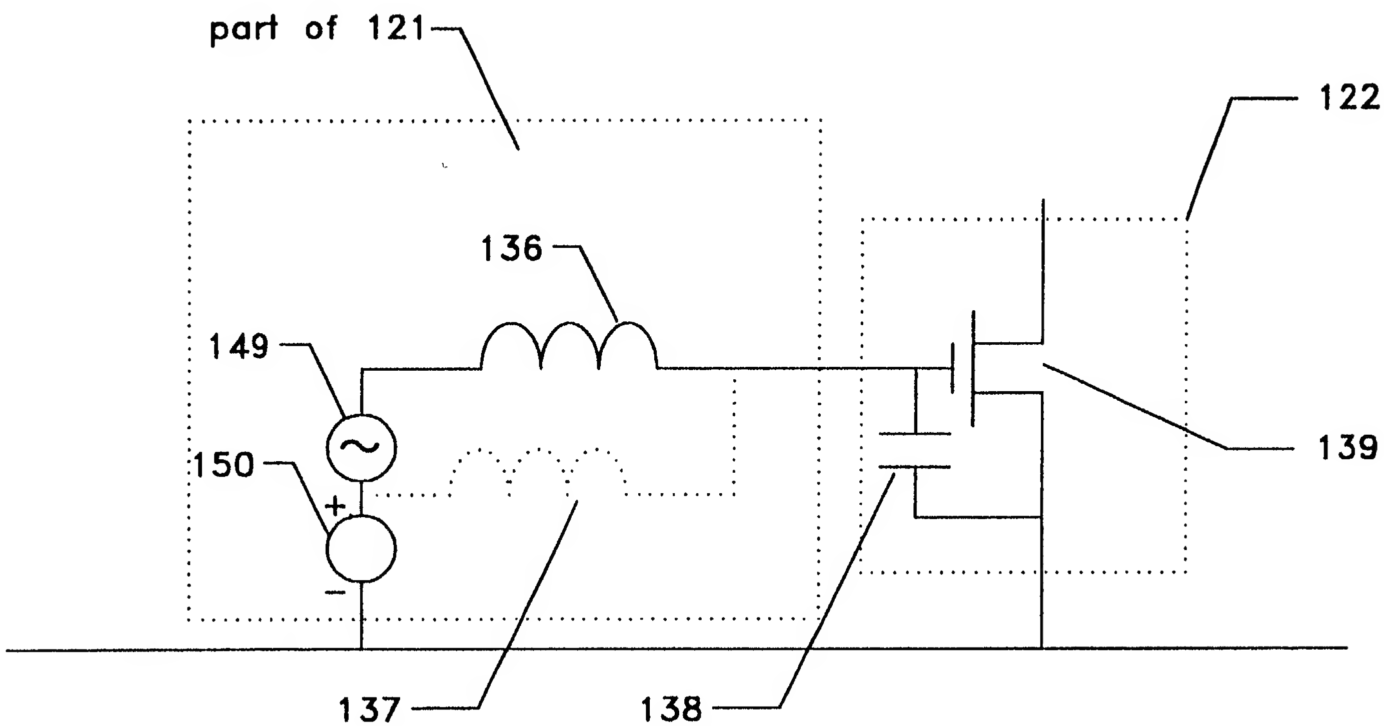


Figure 1–7 – Switch Drive Details

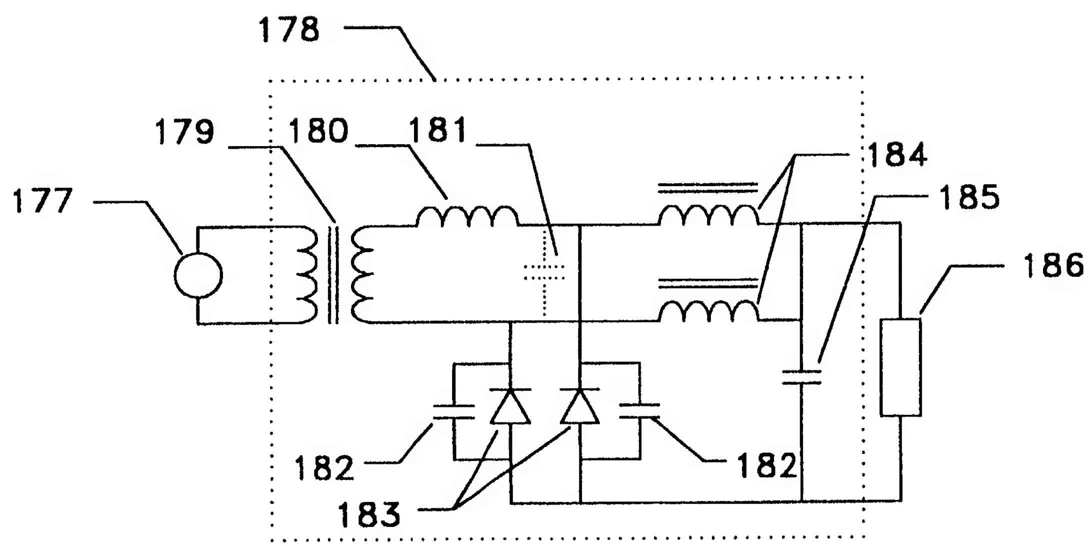
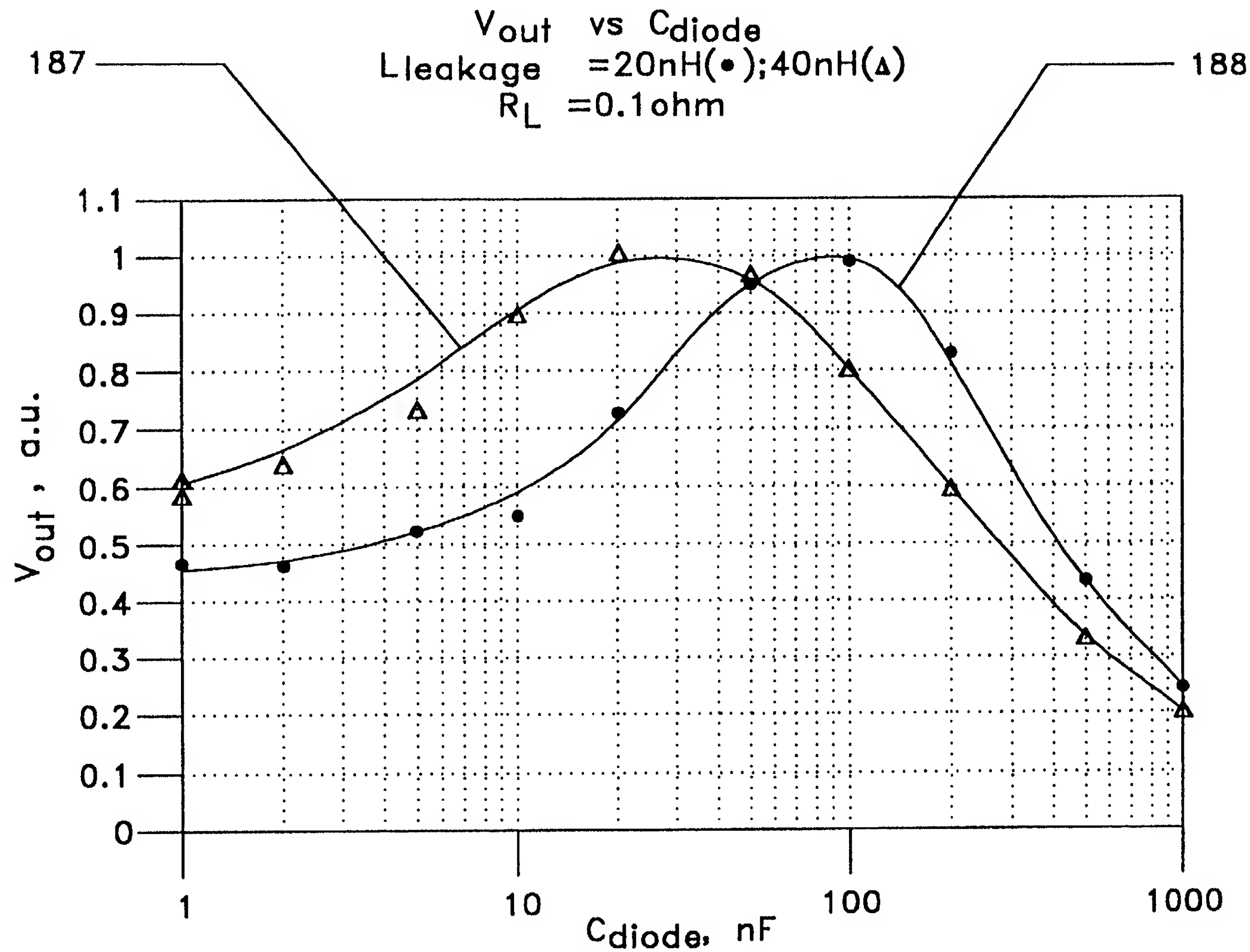


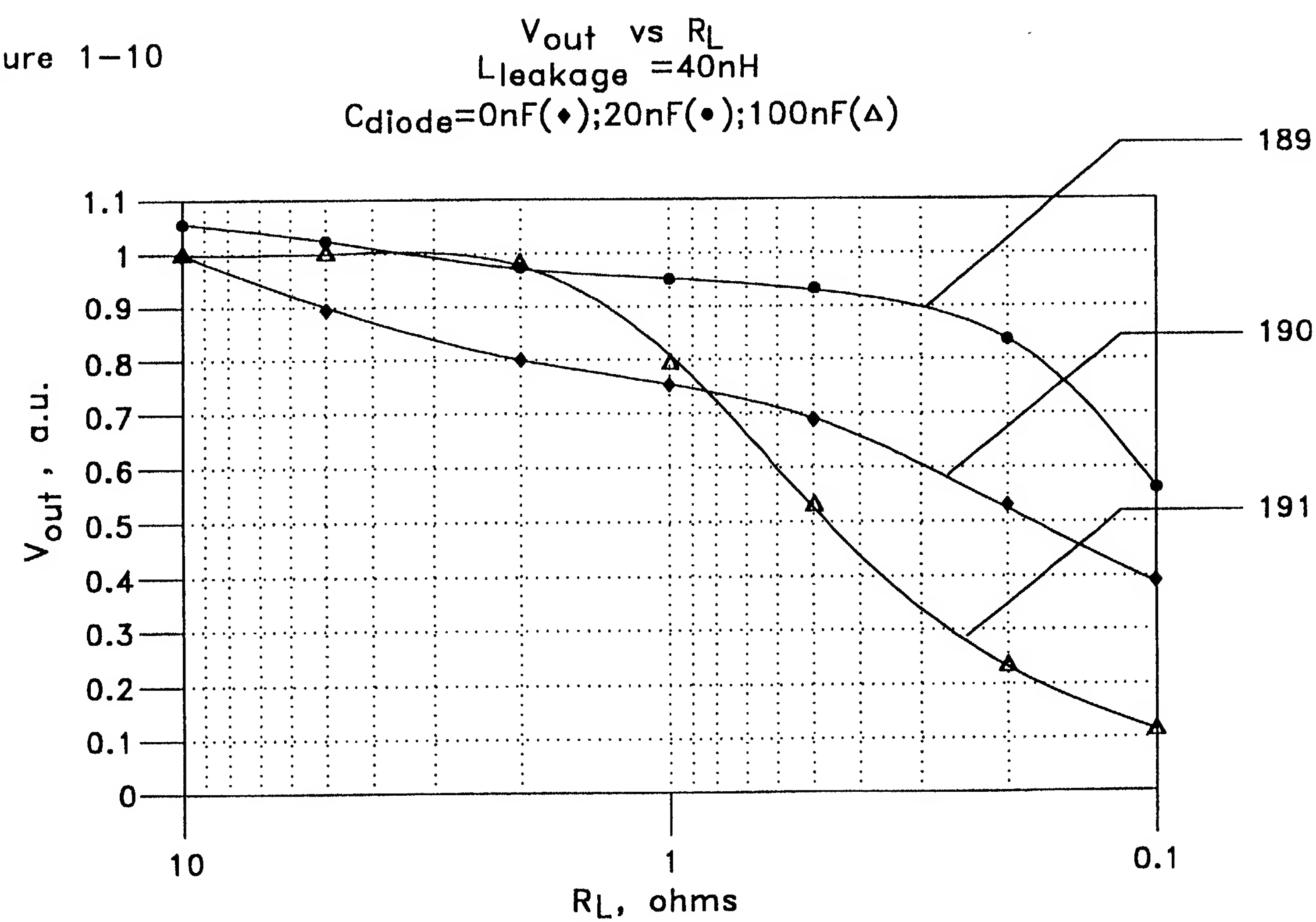
Figure 1–8 – Rectifier Circuit

Figure 1-9



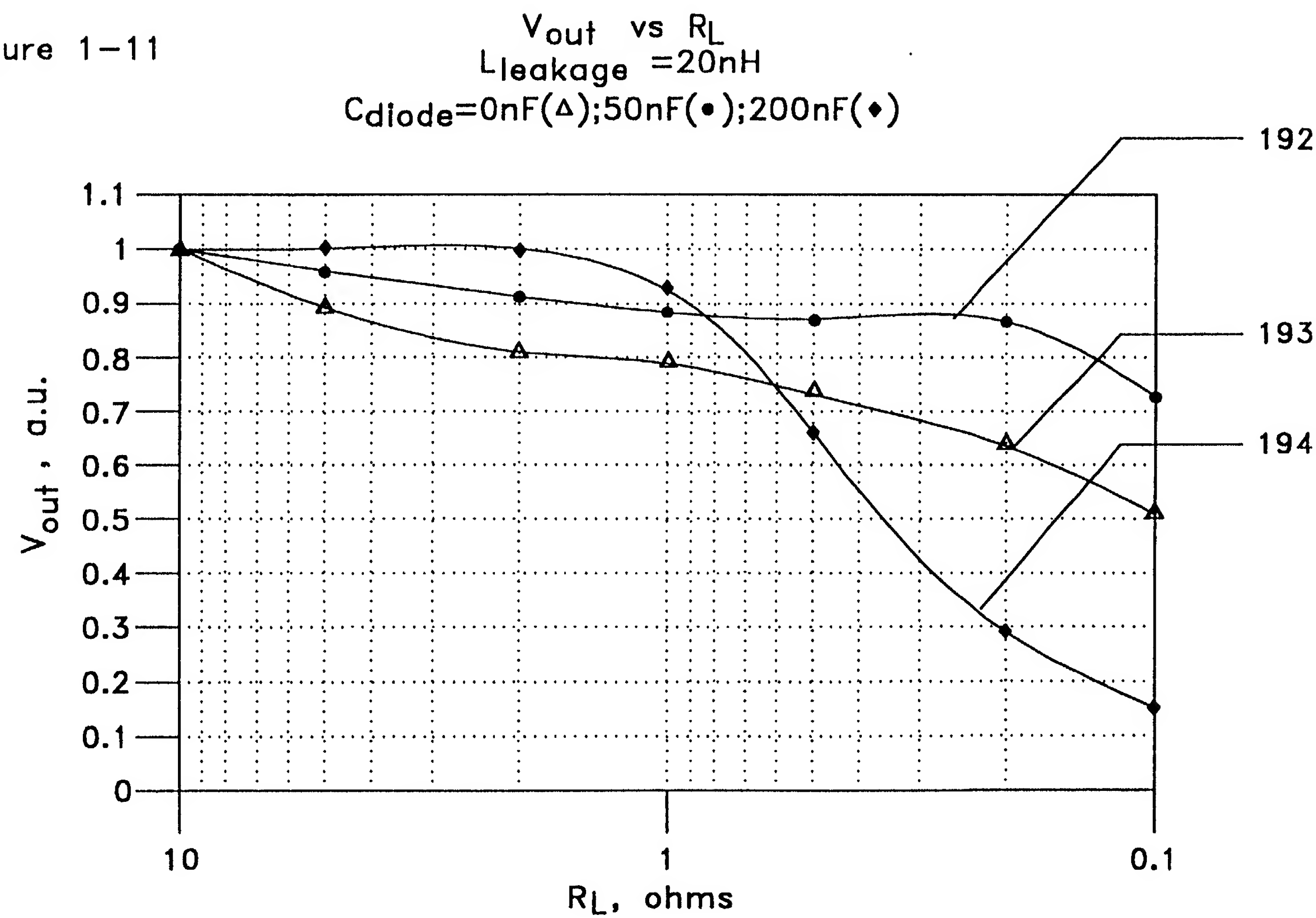
10/030379

Figure 1–10



V_{out} vs R_L
$L_{leakage}$ =40nH
Cdiode=0nF(♦);20nF(•);100nF(Δ)
189
190
191
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
V_{out} , a.u.
10
1
0.1
R_L, ohms

Figure 1–11



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10/030379

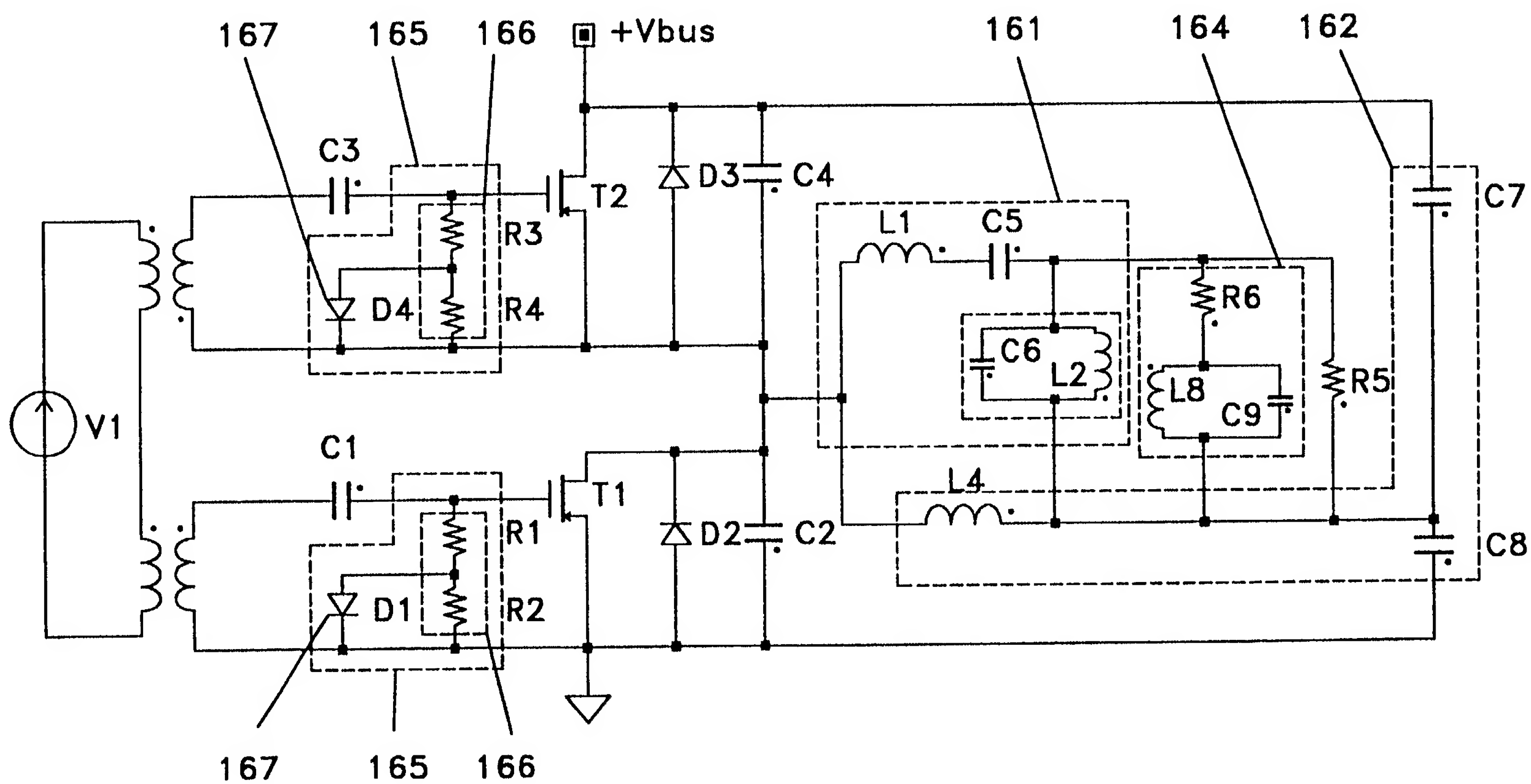
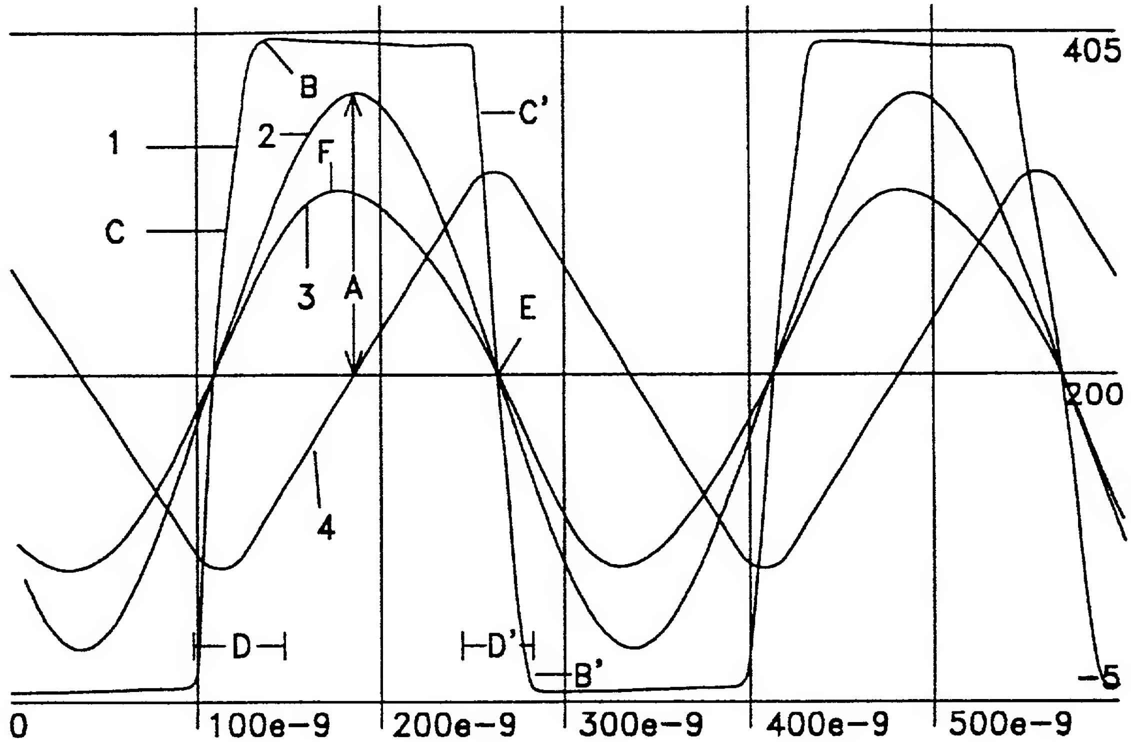
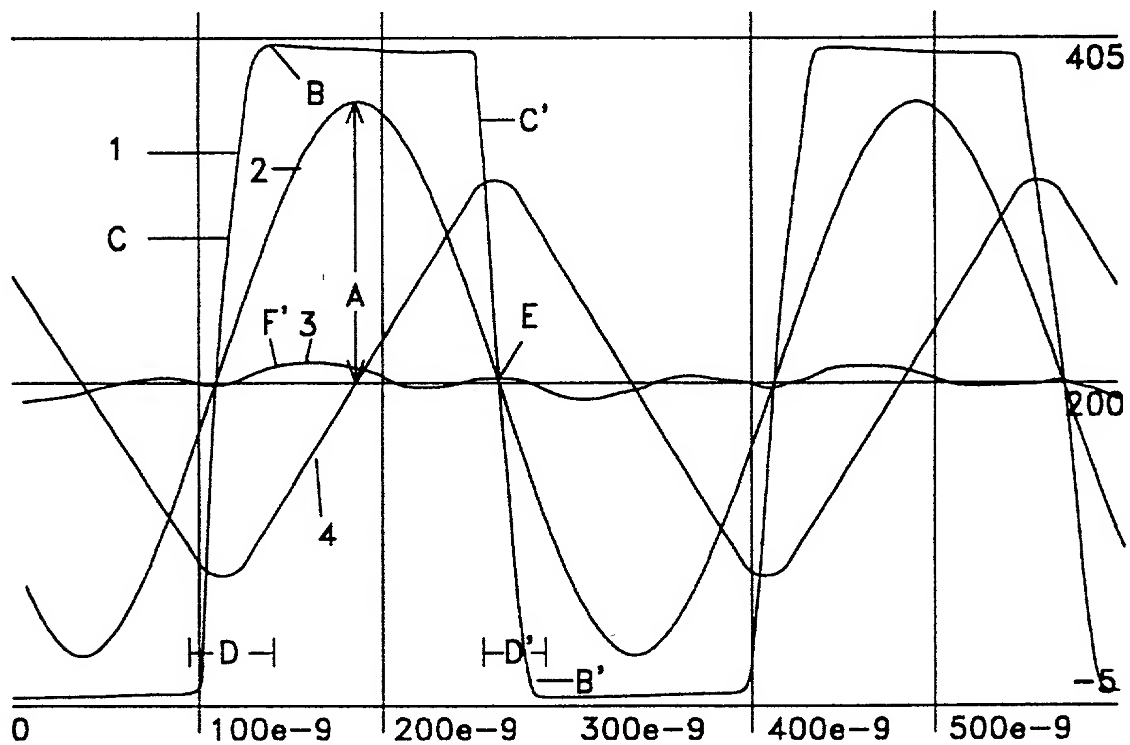


Figure 1-12



300 Watts Output Figure 1-13



30 Watts Output Figure 1-14

10/030379

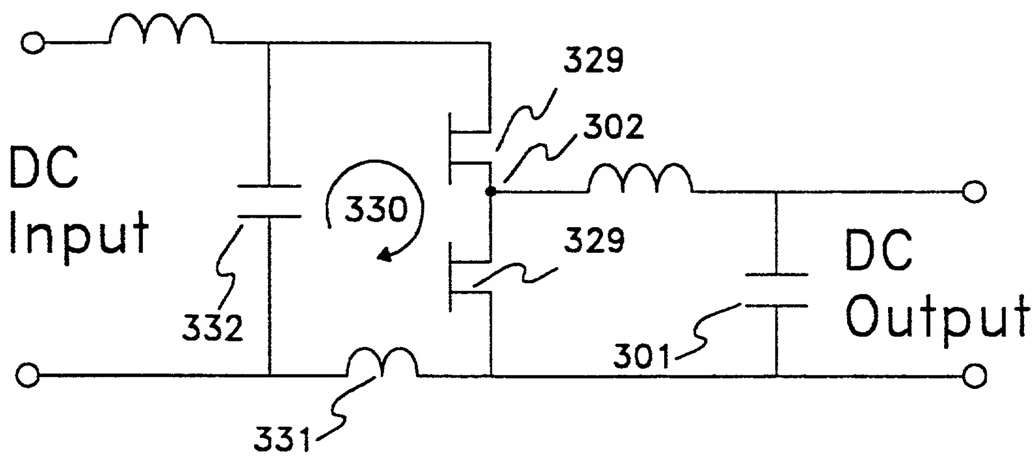


Figure 3-1 (Prior Art)

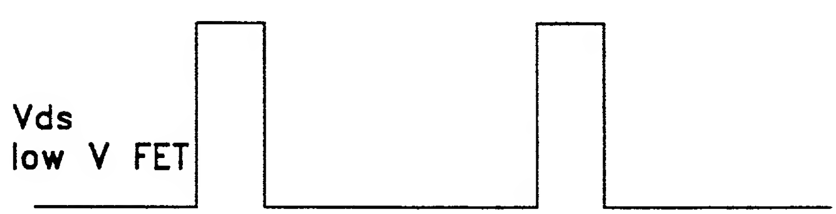


Figure 3-2 (Prior Art)

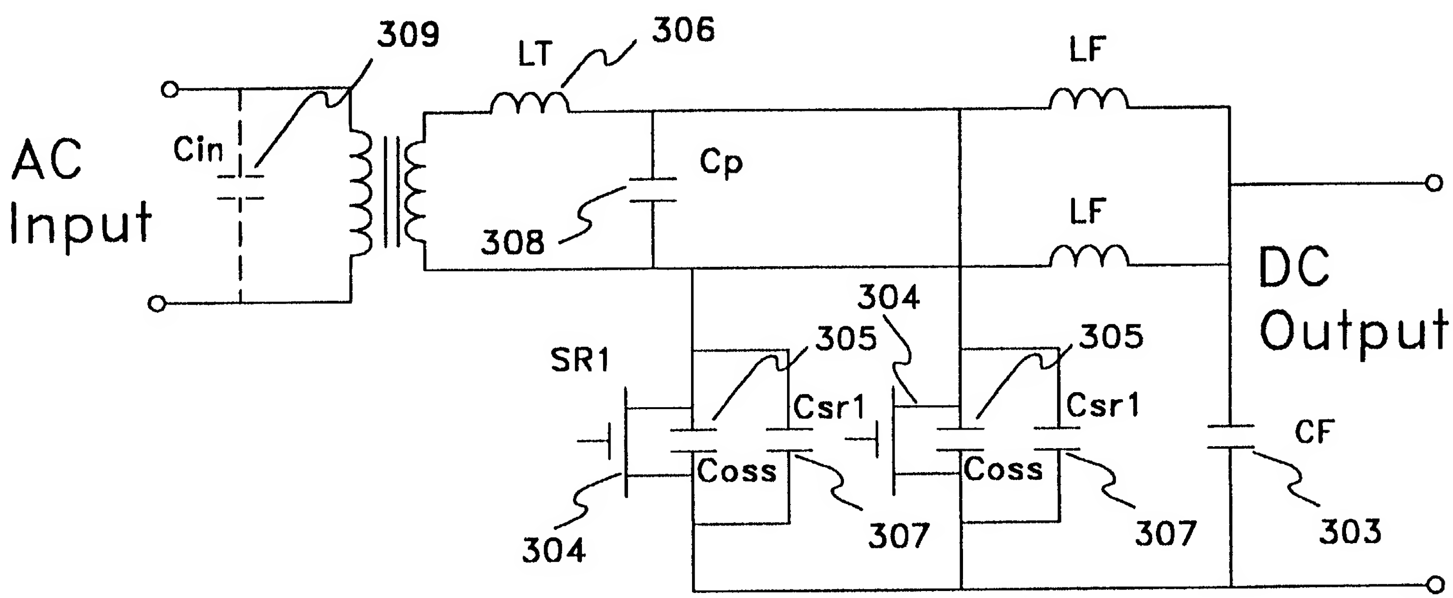

309
LT
306
LF
AC
Input
Cin
Cp
308
LF
DC
Output
304
305
305
SR1
Csr1
Csr1
CF
Coss
Coss
304
307
307
303

Figure 3-3

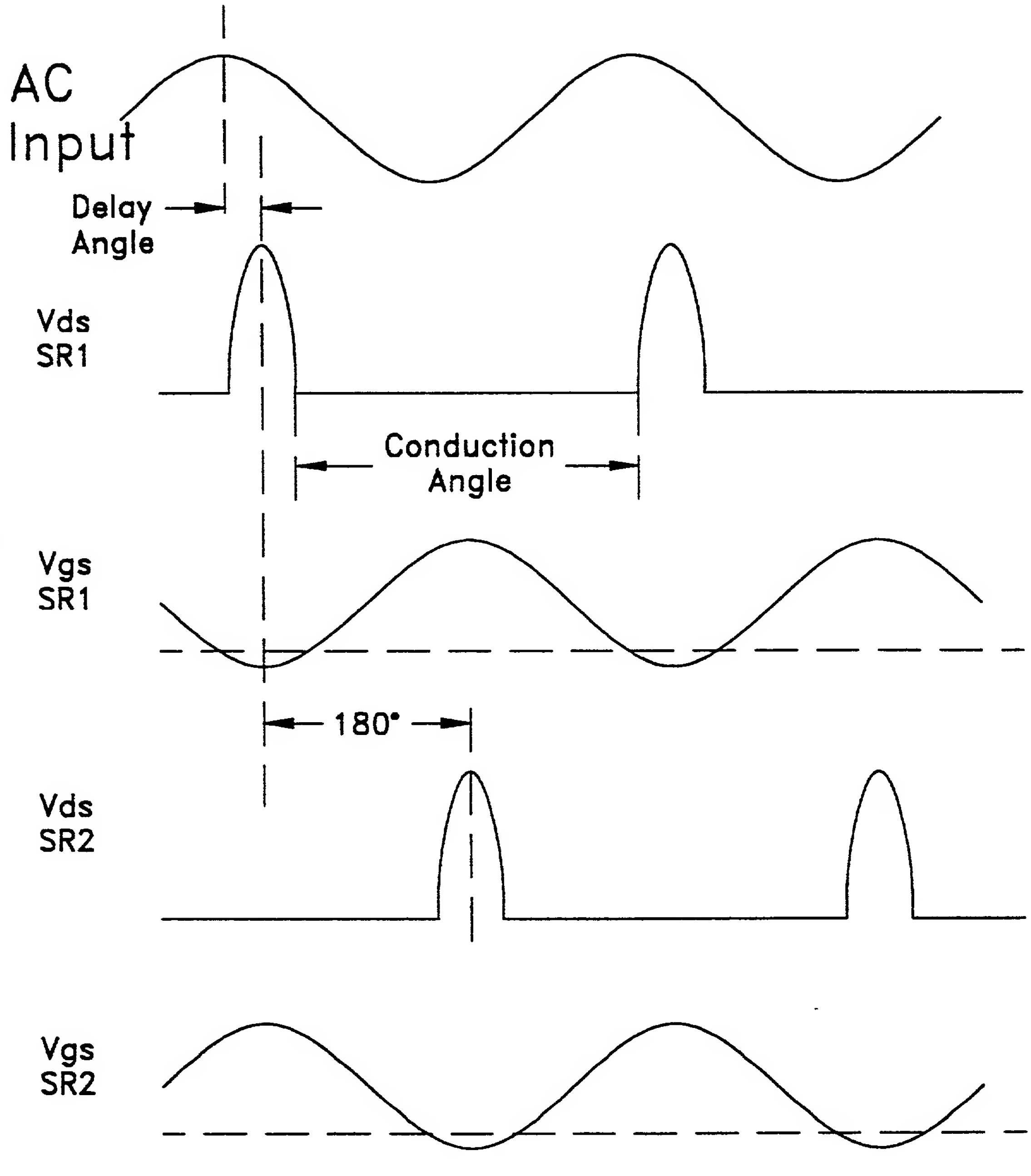

AC
Input
Delay
Angle
Vds
SR1
Conduction
Angle
Vgs
SR1
180°
Vds
SR2
Vgs
SR2

Figure 3-4

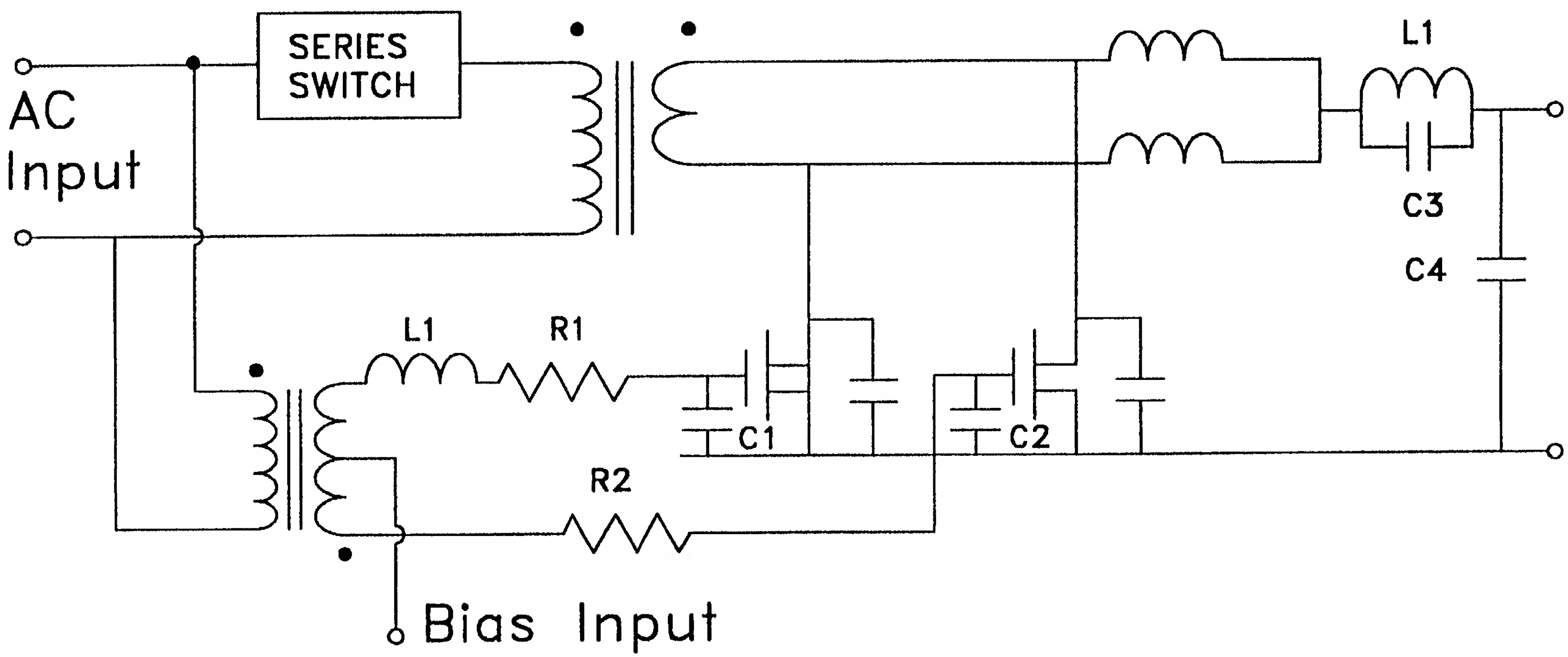


Figure 3-5

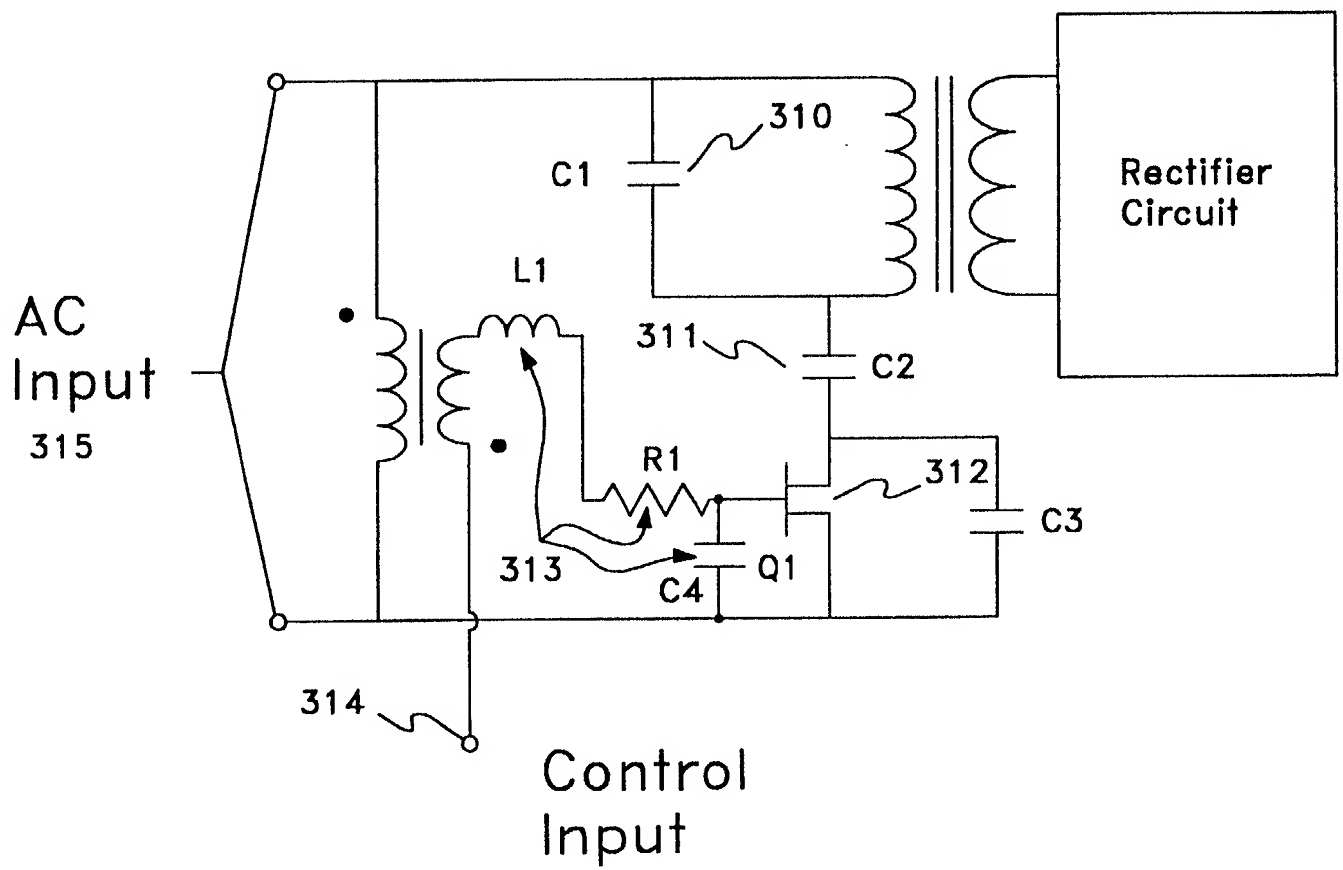

AC
Input
315
L1
C1
310
Rectifier
Circuit
311
C2
R1
312
C3
313
C4
Q1
314
Control
Input

Figure 3—6

Vds on
Q1 Series
Switch FET

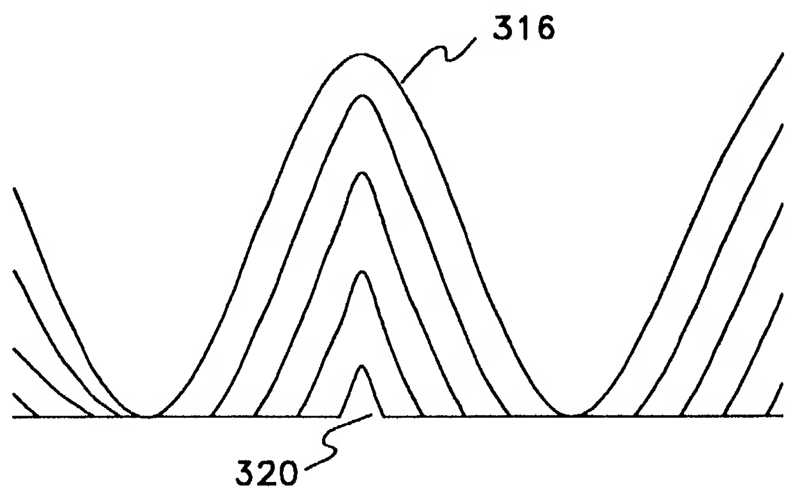


Figure 3–7

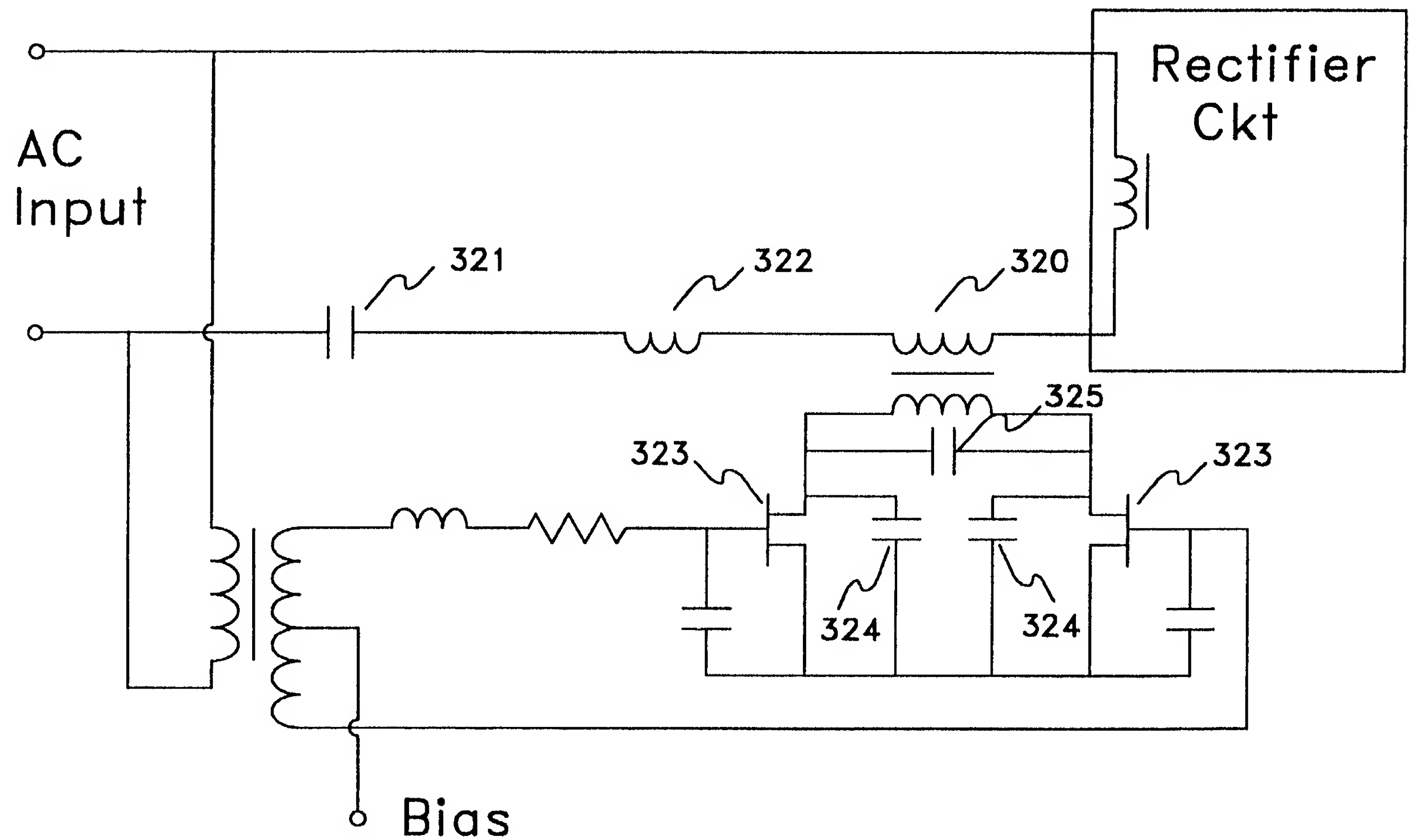
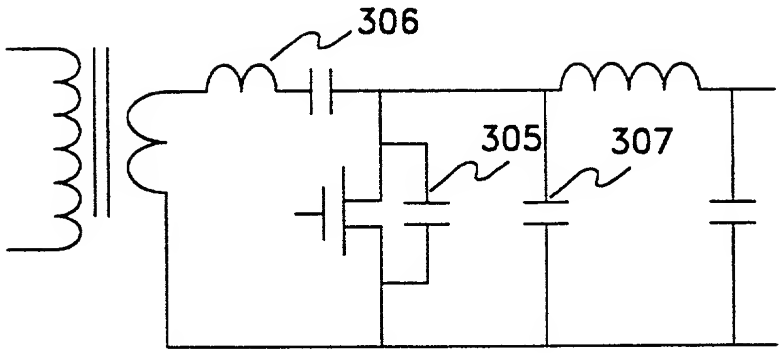
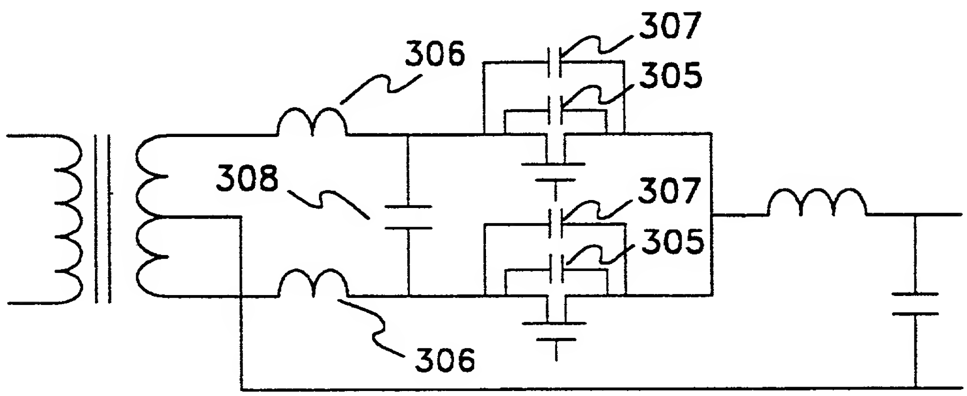


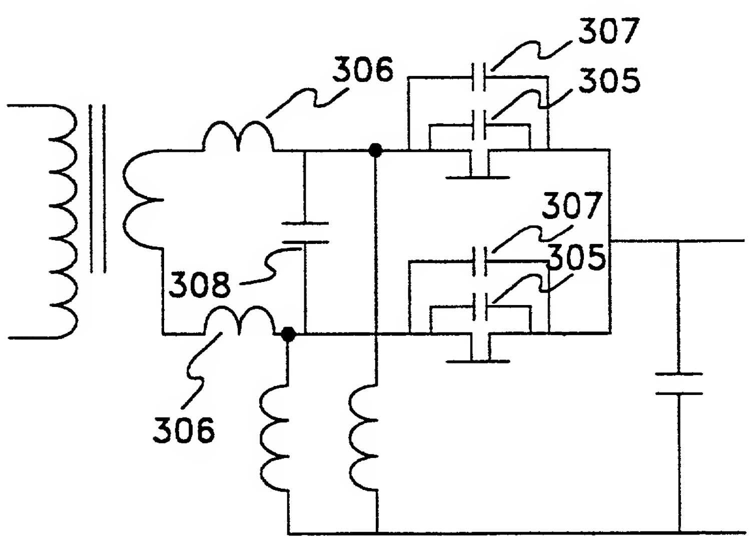
Figure 3–8



A

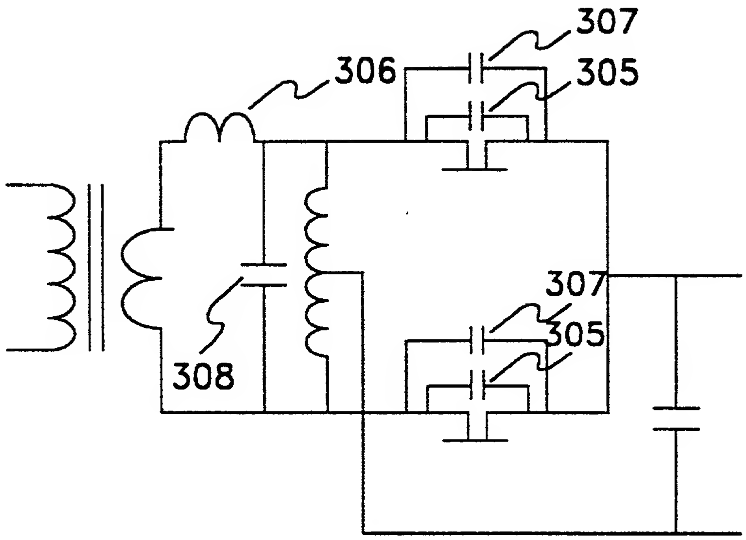


B



C

Figure 3-9



D

Figure 3-9

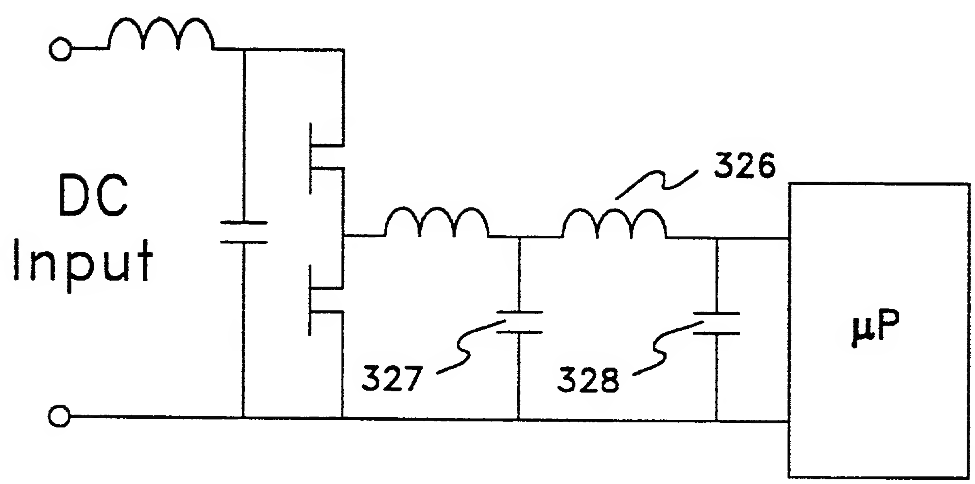


Figure 3–10

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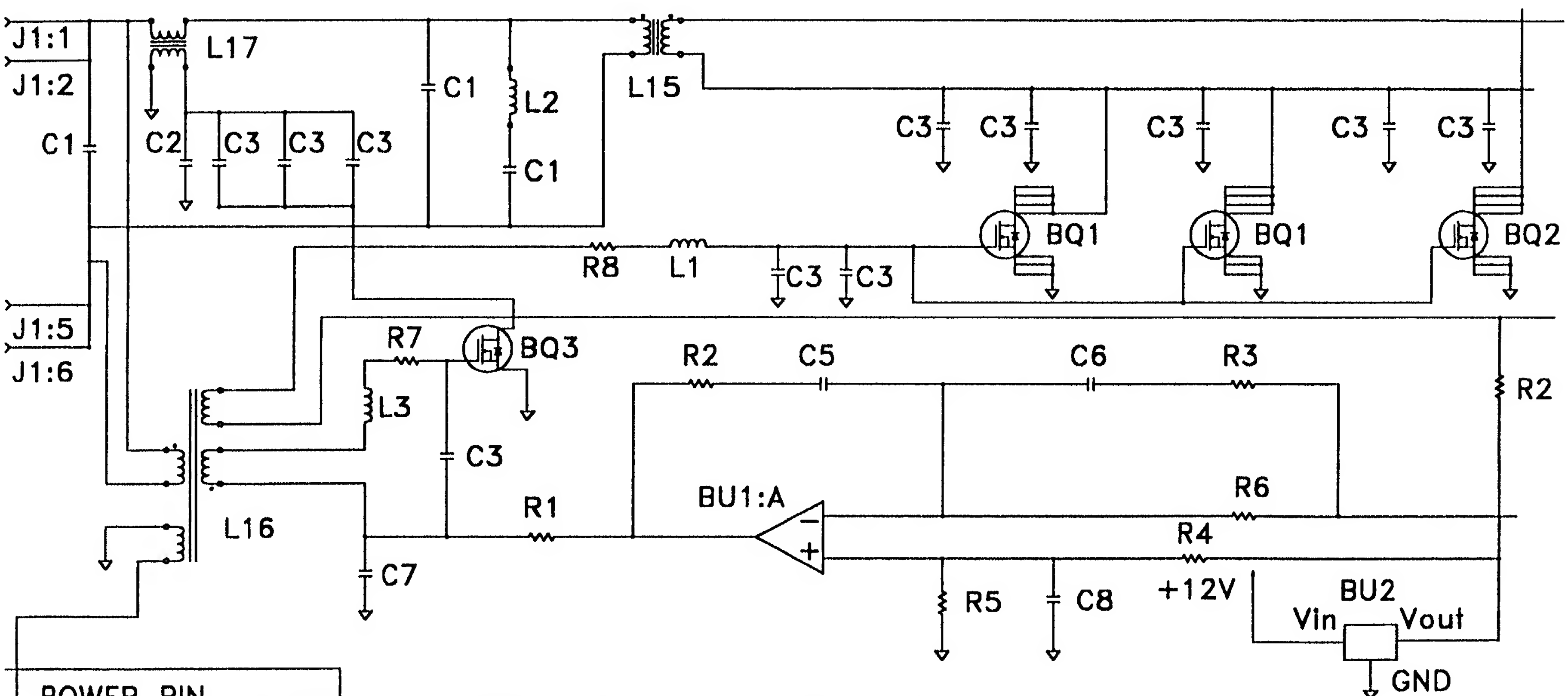
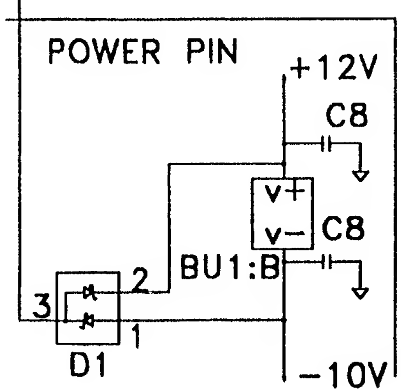




NOTES: UNLESS OTHERWISE SPECIFIED
1) ALL RESISTANCE VALUES ARE IN OHMS, 1/8W, SM, 1%.
2) ALL CAPACITANCE VALUES ARE IN MICROFARADS, 50V.
3) USED WITH 230X131 PCB.
4) ALL REF DES WITH 'B' AS A PREFIX ARE INSTALLED ON SOLDER SIDE.

Figure 3-11 Left

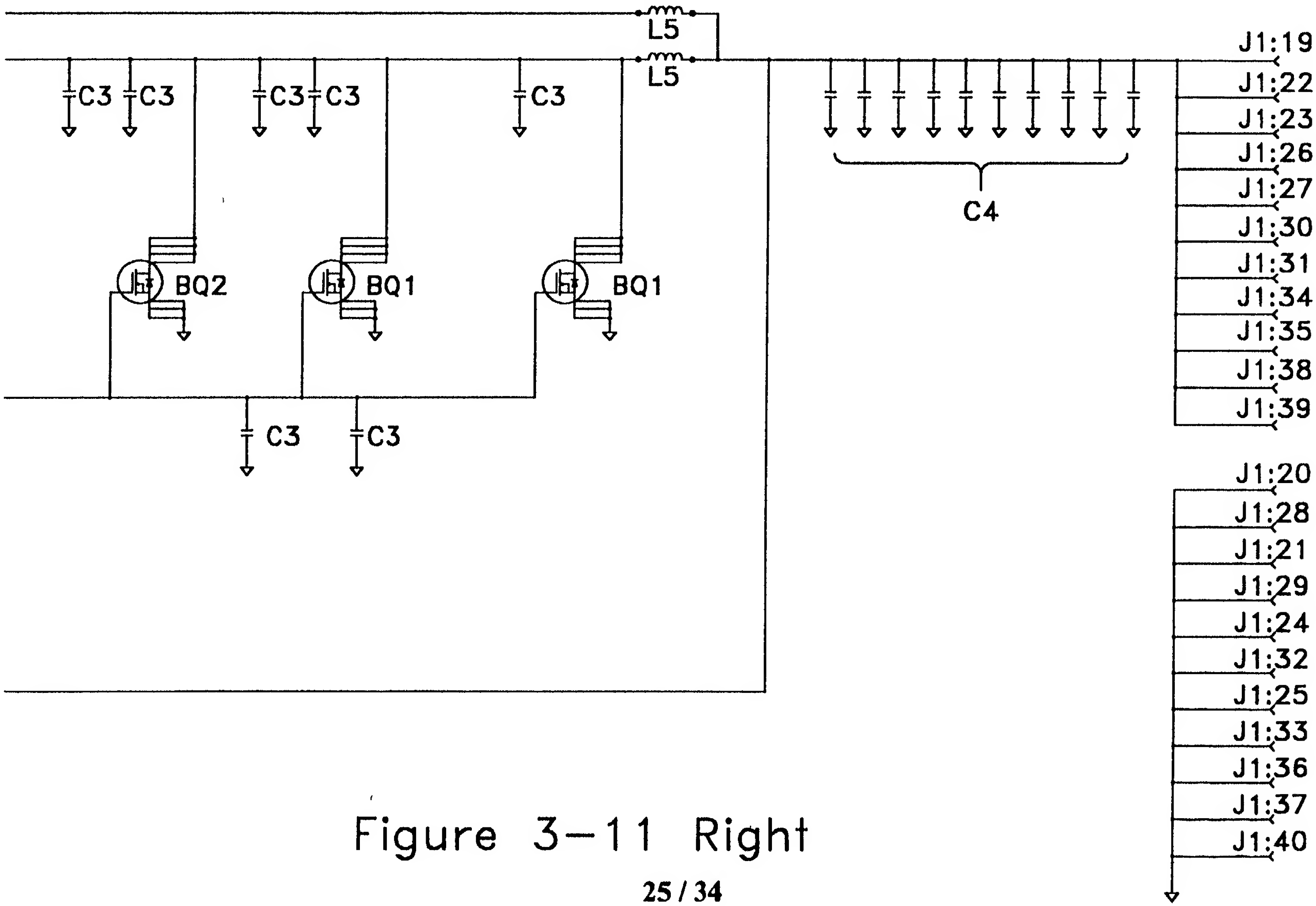


Figure 3–11 Right

Capacitors

C1	470PF	100V
C2	1000PF	100V
C3	2200PF	
C4	22PF	10V
C5	100PF	100V
C6	4700PF	100V
C7	5600PF	100V
C8	0.1	

Resistors

R1	124	
R2	10K	
R3	49.9	
R4	3.24K	
R5	1.82K	
R6	499	
R7	5.6	1/2W 5% SM
R8	0.1	1/2W SM

Inductors

L1	330NH
L2	No Value
L3	150NH
L5	100NH

Miscellaneous

BU1:A	AD825
BU1:B	AD825
BU2	AD1585

Transformers

L15	TRANS	L2
L16	TRANS	L4
L17	TRANS	L6

D1	HSMS2802

Transistors

BQ1	OPEN
BQ2	M14420T
BQ3	Q1 NOTEST

Figure 3-11 Values

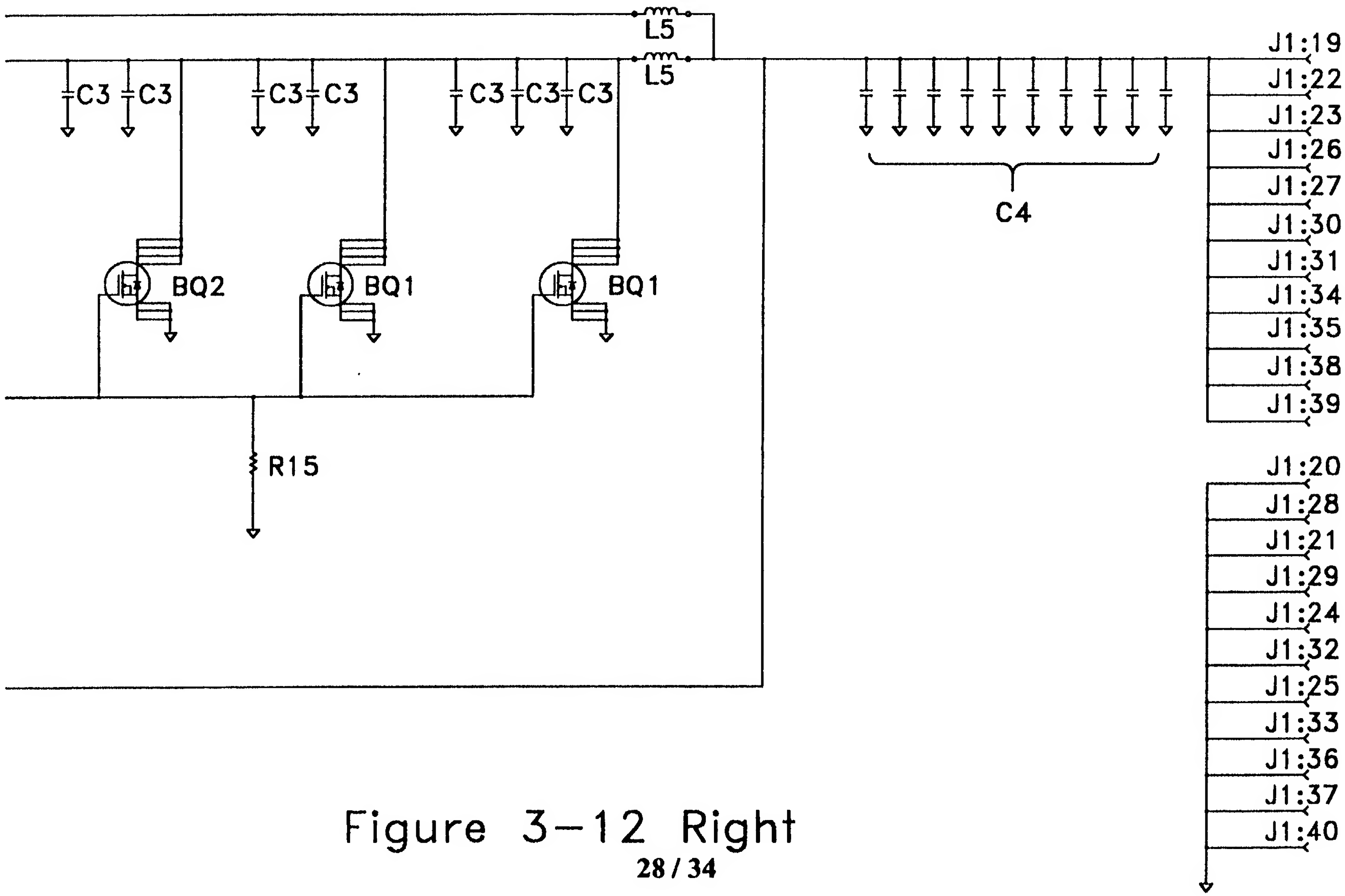
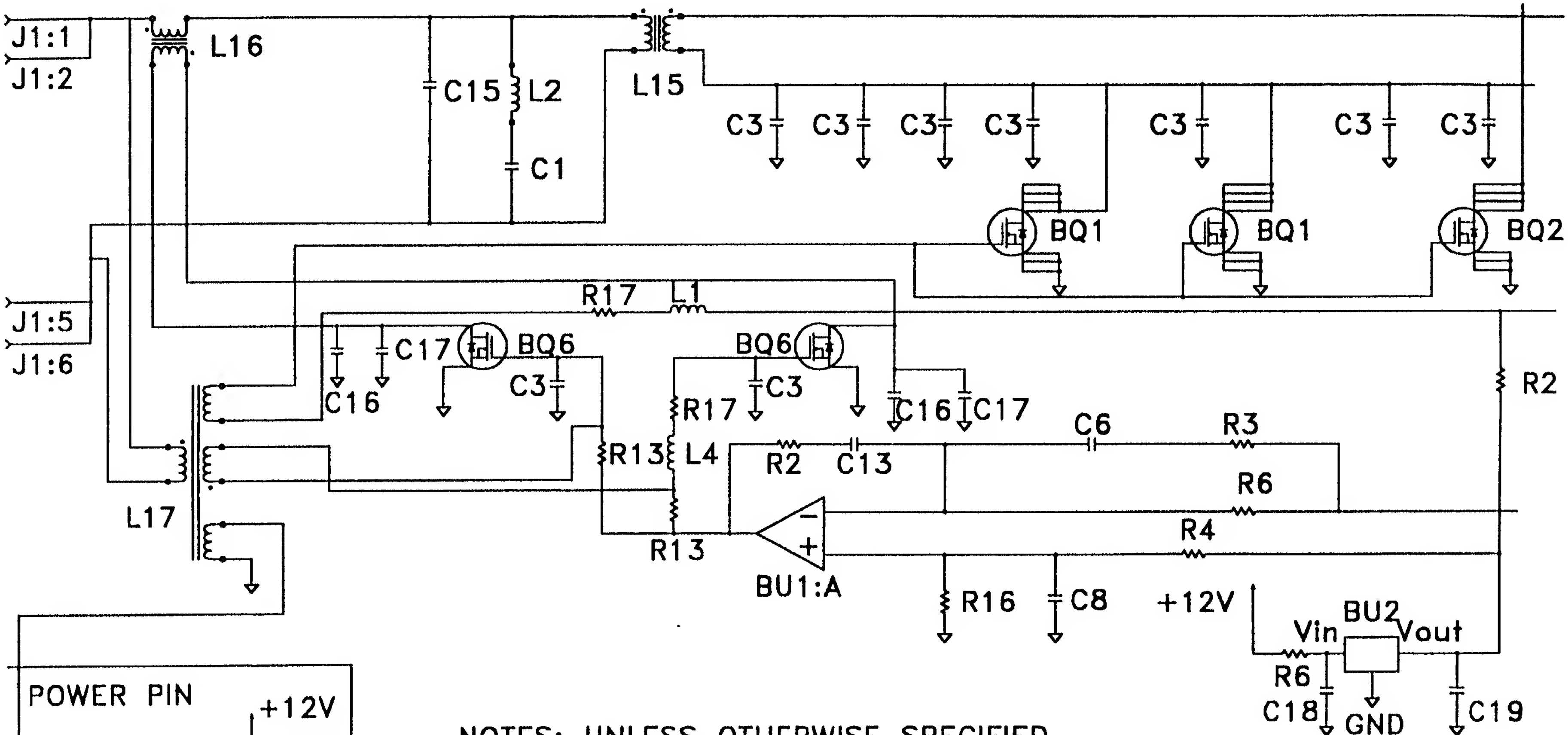
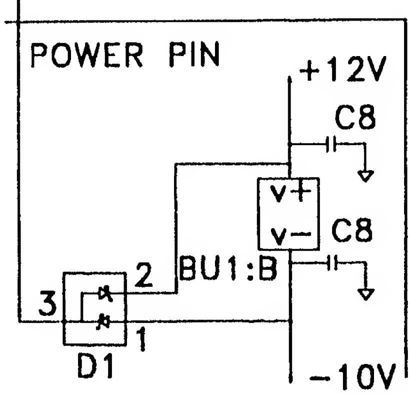


Figure 3–12 Right

10/030379

10/030379





NOTES: UNLESS OTHERWISE SPECIFIED

1) ALL RESISTANCE VALUES ARE IN OHMS, 1/8W, SM, 1%.
2) ALL CAPACITANCE VALUES ARE IN MICROFARADS, 50V.
3) USED WITH 230X131 PCB.
4) ALL REF DES WITH 'B' AS A PREFIX ARE INSTALLED ON SOLDER SIDE.

Figure 3–12 Left

Capacitors

C1	470PF	100V
C3	2200PF	
C4	22PF	10V
C6	4700PF	100V
C8	0.1PF	
C15	1500PF	50V
C16	2700PF	100V
C17	680PF	100V
C18	4.7uF	
C19	1uF	

Inductors

L1	330NH
L2	No Value
L4	OPEN
L5	100NH

Transformers

L15	TRANS	L2
L16	TRANS	L4
L17	TRANS	L6

Resistors

R2	10K
R3	49.9
R4	3.24K
R6	499
R13	100
R15	24.9K
R16	1.82K
R17	OPEN 1/2W

Miscellaneous

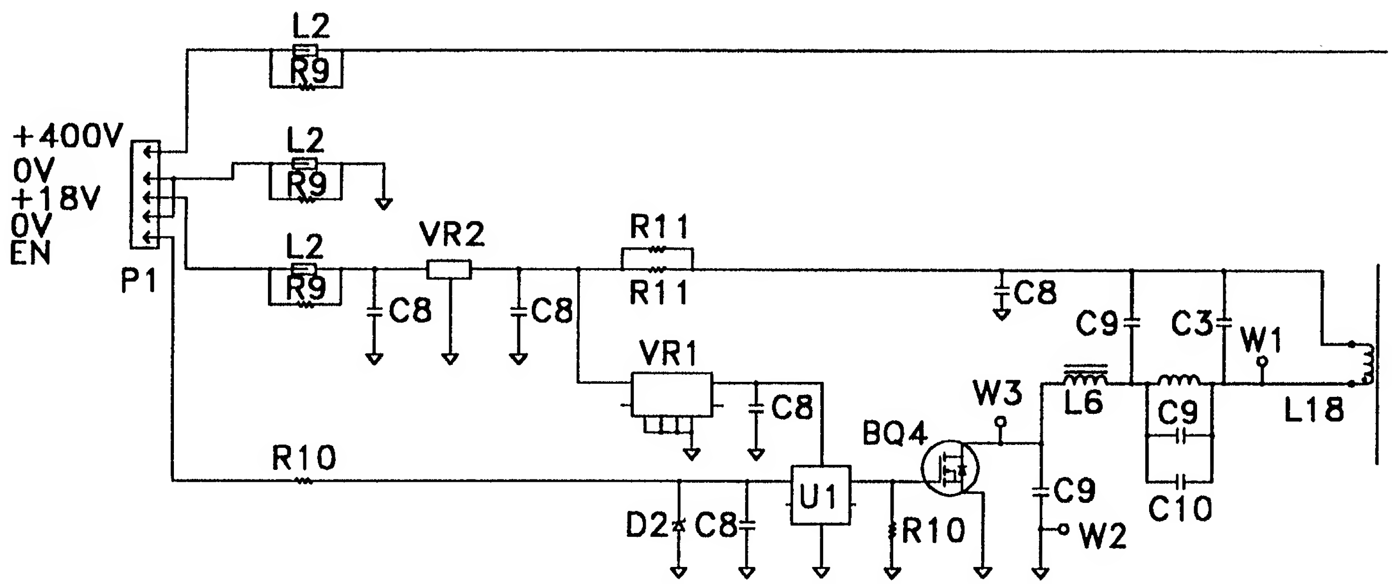
BU1:A	AD825
BU1:B	AD825
BU2	AD1585

D1	HSMS2802

Transistors

BQ1	OPEN
BQ2	M14420T
BQ6	RFD16NO06LESM

Figure 3-12 Values



NOTES: UNLESS OTHERWISE SPECIFIED

1) ALL RESISTANCE VALUES ARE IN OHMS, 1/8W, SM, 1%.
2) ALL CAPACITANCE VALUES ARE IN MICROFARADS, 50V.
3) USED WITH 2305684 PCB.
4) ALL REF DES WITH 'B' AS A PREFIX ARE INSTALLED ON SOLDER SIDE.

Figure 3-13 Left

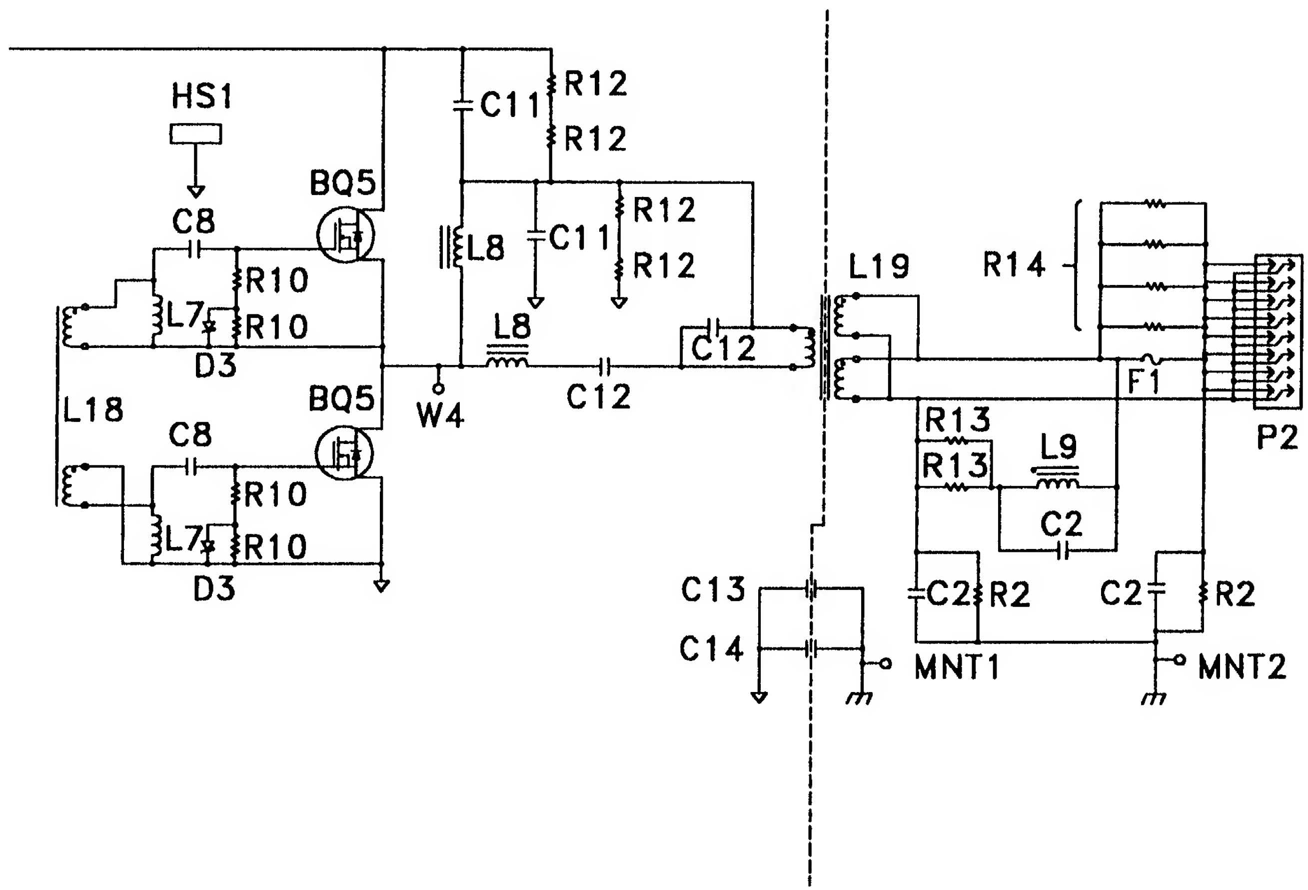


Figure 3-13 Right

Capacitors

C2	1000PF	
C3	2200PF	
C8	0.1PF	
C9	220PF	100V
C10	150PF	100V
C11	0.1PF	500V
C12	270PF	1KV
C13	OPEN	
C14	2200PF	250VAC

Resistors

R2	10K
R9	OPEN
R10	1K
R11	10
R12	200K
R13	100
R14	0

Inductors

L2	No Value
L6	5.6UH
L7	1.5UH
L8	6.2UH
L9	2.2UH

Miscellaneous

D2	5.6V
D3	________

Transformers

L18	TRANS	T1
L19	TRANS	T2

U1	P1	E/D
	P2	NC
	P3	GND
	P4	OUT
	P5	NC

Transistors

BQ4	NDS7002A
BQ5	IRF840LC

VR1	P1	V (OUT) LM78L05
	P2, 3, 6, 7	GND
	P4	NC
	P5	NC
	P8	V(IN)

HS1 HEAT SINK

F1 FUSE OPEN

VR2	P1	78M15CDT
	P2	GND

Figure 3-13 Values

10/030379

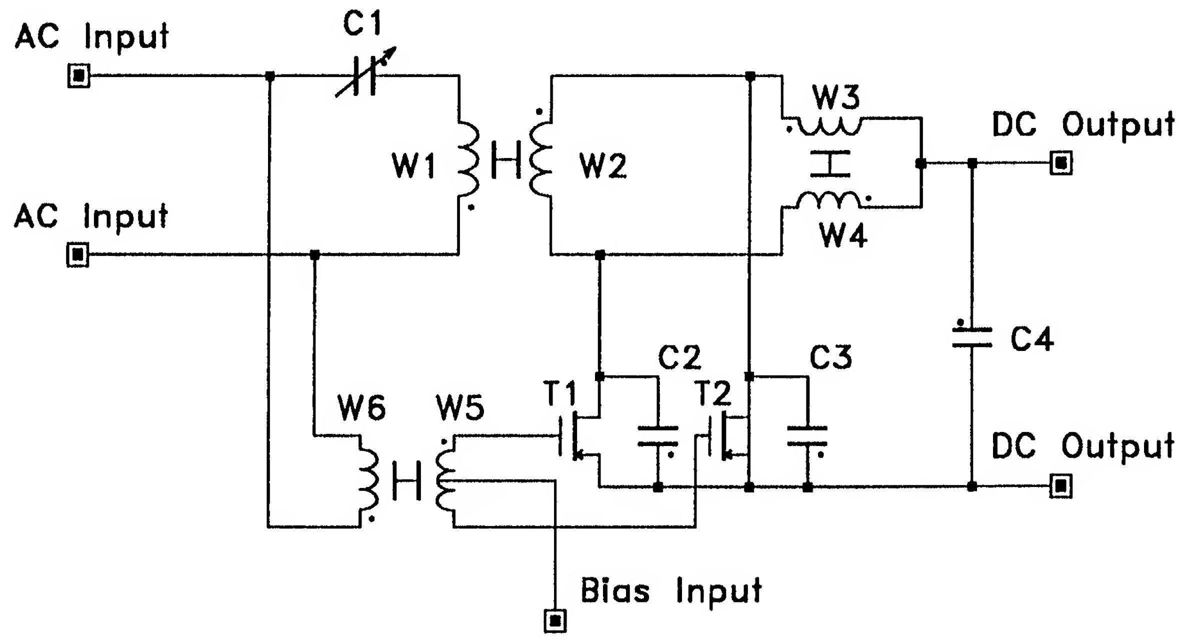


FIG. 3-14

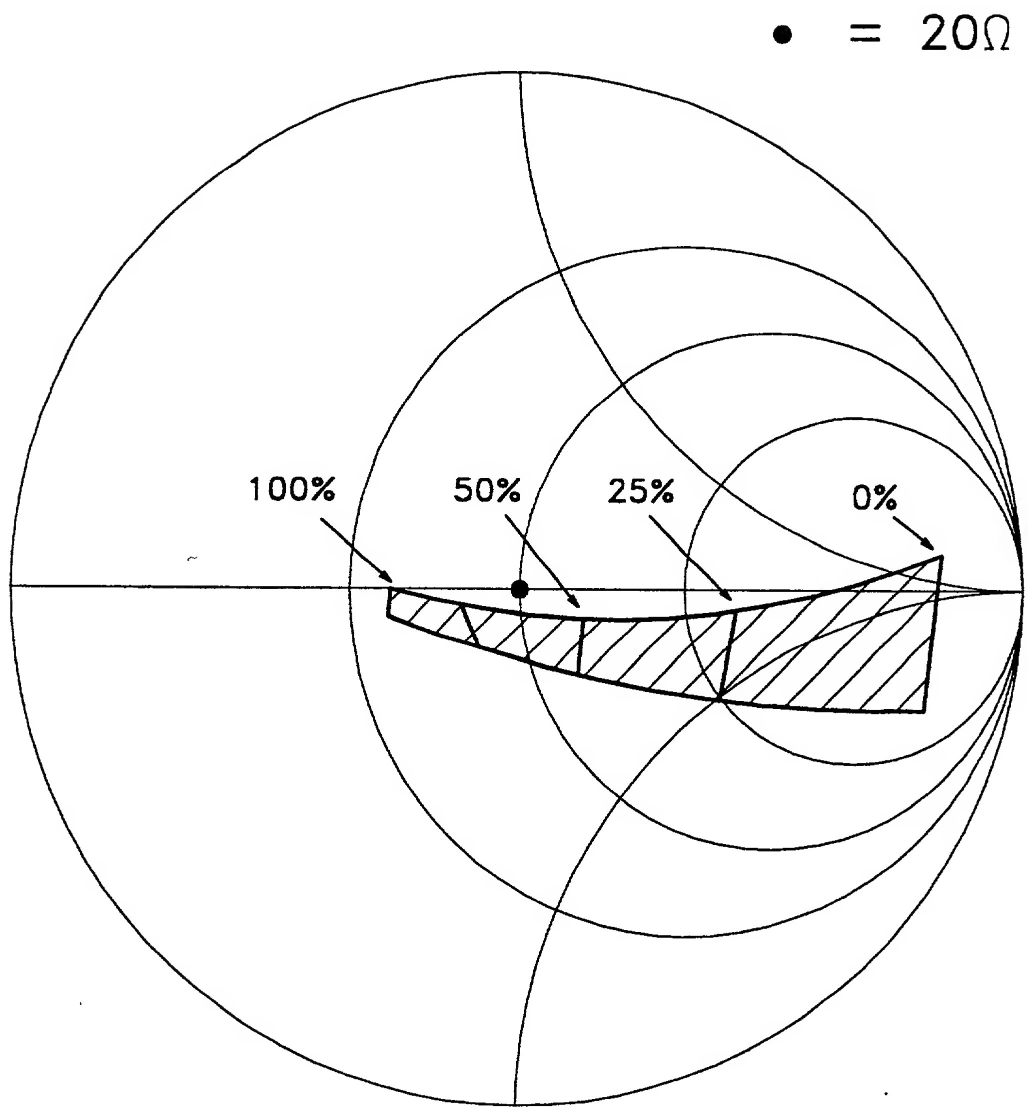


FIG. 3-15

Express Mail No: EL913300238US
Attorney Docket: AEI VRM USNP1

IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE

In Re the Application of:	Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov	
Serial Number:	(original US) 60/142,102 (PCT) PCT/US00/18086	New: ________
Filed:	(original US) 02 July 1999 (PCT) 30 June 2000	New: ________
For:	(Old Title): System for Controlling the Delivery of Power to DC Computer Components (New Title): Multiple Element Rectification Circuit	

DECLARATION FOR PATENT APPLICATION

This Declaration is made by Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov.

1-00

I, Robert M. Porter, hereby declare:

- I am a citizen of the United States of America and that my residence and mailing address is 114 Arikaree Peak Drive, Livermore, CO 80536. CO

2-00

I, Anatoli V. Ledenev, hereby declare:

- I am a citizen of the Russian Federation and am now residing in the United States of America and that my residence and mailing address is 719 Parliament Court, Fort Collins, Colorado, 80525. CO

3-00

I, Gennady G. Gurov, hereby declare:

- I am a citizen of the Russian Federation and am now residing in the United States of

America and that my residence and mailing address is 4936 Dakota Drive, Fort Collins, Colorado, 80525.

We, Robert M. Porter, Anatoli V. Ledenev, and Gennady G. Gurov, each hereby declare:

We believe that we are the original, first, and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled "Multiple Element Rectification Circuit" and:

- as originally entitled "System for Controlling the Delivery of Power for Low Voltage, High Current Applications" the specification of which was filed as United States Application Number 60/142,102 filed July 2, 1999;
- as originally entitled "Improved Method and Apparatus for Powering Low Voltage High Current Electronics" the specification of which was filed as United States Application Number 60/144,342 filed July 16, 1999;
- as originally entitled "High Frequency Switch-mode DC Powered Computer System" PCT Application Number PCT/US00/07779 the specification of which was filed on March 23, 2000 and designating the United States of America, this PCT Application being filed while the Original US Application was pending;
- as originally entitled "System for Controlling the Delivery of Power to DC Computer Components" PCT Application Number PCT/US00/18086 the specification of which was filed on June 30, 2000 and designating the United States of America, this PCT Application being filed while the Original US Application was pending;
- as originally entitled "High Frequency Switch-mode DC Powered Computer System" the specification of which was filed as United States Application Number 09/534,641 filed March 23, 2000; and also
- as originally entitled "System for Controlling the Delivery of Power to DC Computer Components" the specification of which was filed as United States Application Number 09/584,412 filed May 31, 2000;

the specification(s) of which has/have been provided to me/us at or prior to the time of signing this declaration, and of which we hereby claim the benefit of and priority pursuant to 35 USC §§119, 120, or 365; there are no foreign applications having a filing date before that of the application(s) on which priority is claimed; and, if applicable, I/we have identified in the request of this application, in compliance with PCT Rule 4.10, any claim to foreign priority and I/we have identified above by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.

We hereby declare that the above specification(s) is/are intended to include disclosure or claims directed to, individually or in combination: embodiments of the invention which may encompass a

device, apparatus, method, process, or business method; embodiments of the invention which may encompass permutations or combinations of any aspects of the invention; any aspect of the invention conceived or developed as separate inventions; and any aspect of the invention independent of any initial context considered as preferred embodiments. We also authorize and support this application for patent protection in the United States, and for similar protection in foreign countries, each to be sought to the extent or breadth any owner desires or deems appropriate. We acknowledge that each of the attorneys and the firm filing this application is/are attorneys for the assignee, Advanced Energy Industries, Inc. only.

We hereby state that we have reviewed and understand the contents of the specification entitled "Multiple Element Rectification Circuit", including any claims.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: Jan 2, 2002

Robert M. Porter

UNITED STATES OF AMERICA)
STATE OF COLORADO)ss.
COUNTY OF LARIMER)

SUBSCRIBED AND AFFIRMED OR SWORN to before me in the County of Larimer, State of Colorado, United States of America, by Robert M. Porter, this 2nd day of January, 2002.

WITNESS my hand and official seal pursuant to the authority vested in me as a Notary Public by the State of Colorado.

Patricia Sortom
Notary Public
My Commission Expires: March 2, 2002

Date: 01/02/2002

Anatoli V. Ledenev

UNITED STATES OF AMERICA)
STATE OF COLORADO)ss.
COUNTY OF LARIMER)

SUBSCRIBED AND AFFIRMED OR SWORN to before me in the County of Larimer, State of Colorado, United States of America, by Anatoli V. Ledenev, this 2nd day of January, 2002.

WITNESS my hand and official seal pursuant to the authority vested in me as a Notary Public by the State of Colorado.

Patricia Sortom
Notary Public
My Commission Expires: March 2, 2002

Date: Jan 2, 2002

Gennady G. Gurov

UNITED STATES OF AMERICA)
STATE OF COLORADO)ss.
COUNTY OF LARIMER)

SUBSCRIBED AND AFFIRMED OR SWORN to before me in the County of Larimer, State of Colorado, United States of America, by Gennady G. Gurov, this 2nd day of January, 2002.

WITNESS my hand and official seal pursuant to the authority vested in me as a Notary Public by the State of Colorado.

Notary Public
My Commission Expires: March 2, 2002

usnp.decl